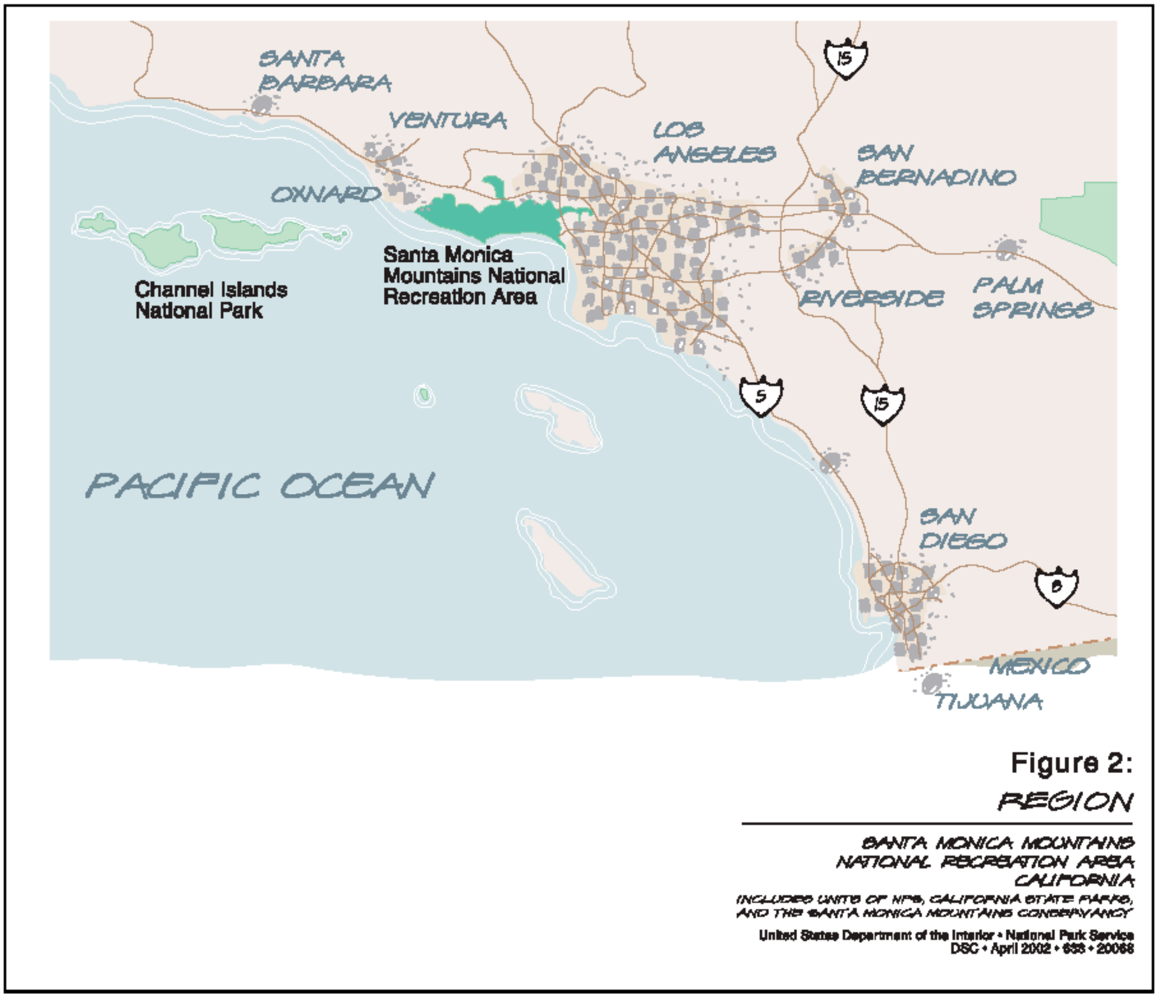
Chapter Three

AFFECTED ENVIRONMENT

1 Overview

The Santa Monica Mountains are coastal mountains that form the southernmost mountain chain in the east-west trending Transverse Range of southern California. The Santa Monica Mountains average 7.5 miles in width and have a mean elevation of 1000 feet. The highest point is Sandstone Peak at 3,111 feet with the lowest elevation occurring along the shore at sea level.

Figure 3-1 Santa Monica Mountains and Vicinity



The Santa Monica Mountains National Recreation Area (SMMNRA) was established by Congress on November 10, 1978 with the following direction:

> *The Secretary of the Interior shall manage the recreation area in a manner which will preserve and enhance its scenic, natural and historic setting and its public health value as an airshed for the Southern California metropolitan area while providing for the recreational and educational needs of the visiting public.*

The SMMNRA is nationally significant because it protects the largest expanse of mainland Mediterranean ecosystem in the national park system. Mediterranean-type ecosystems are globally important because of a limited worldwide geographic distribution and high biological diversity (http://www.biodiversityhotspots.org/xp/Hotspots). There is tremendous ecological diversity within the park including coastal dunes and marshes, grasslands, coastal sage and chaparral shrublands, oak woodlands, valley oak savannas, rocky outcrops, riparian woodlands, suburban and agricultural areas. Fifty species of mammals are found in the mountains including bobcat, mountain lions, mule deer, and badgers. In addition, nearly 400 species of birds, 35 species of reptiles and amphibians, and 1000 species and varieties of plants are known to occur.

The SMMNRA is 153,075 acres. It extends for 46 miles from Griffith Park in Los Angeles to Point Mugu State Park in Ventura County. An additional 69,099 acres are included beyond the recreation area's boundary and define the 220,000 acre Santa Monica Mountain Zone. The SMMNRA includes federal, state and local parklands as well as private property. Approximately 90% of the SMMNRA is still undeveloped with 22,610 acres of federal parkland, 35,059 acres of state parkland and 70,923 acres of private land. Approximately 70,000 people live within the national recreation area. Consequently, the SMMNRA includes a significant amount of urban-wildland interface where developed lands on the boundary and within the recreation area meet areas of undeveloped natural habitat. The patchwork of land ownership and development means that there are complex boundaries between parkland and private property and correspondingly complex fire management issues.

Table 3-1 Current Park Ownership

OWNER	ACRES	PROTECTED PARKLAND
National Park Service	22,610	22,610
Other Federal Land	936	
State Dept of Parks & Recreation	35,059	35,059
Mountains Recreation & Conservation Authority	7,712	7,712
Santa Monica Mountains Conservancy	5,079	5,079
University of CA Reserve	328	328
Los Angeles County Parkland	1,074	1,074
Other L.os Angeles County Land	3,286	
City of Los Angeles Parkland	437	437
Other City of L.os Angeles Land	1,998	
Conejo Open Space Foundation (COSCA)	0	
City of Thousand Oaks Parkland	36	36
City of Calabasas Parkland	245	245
Las Virgenes Municipal Water District	1,198	
Miscellaneous Public Land	254	
Other Private Land	70,923	
Mountains Restoration Trust	1,900	1,900
Totals:	**153,075**	**74,480**

In addition to the outstanding biological resources of the park, the cultural resources of the park are rich and varied. The Santa Monica Mountains are home to two of the largest Native American Indian groups in California, the Chumash and the Gabrielino/Tongva. Within the park boundaries there are over 1000 archeological sites, the earliest dating from 5000 BC. More recent cultural resources are associated with the emergence of the movie industry in the Los Angeles area which was dependent upon the easily accessible and varied topography of the Santa Monica Mountains.

No other national park features such a diverse assemblage of natural, cultural, scenic, and recreational resources within easy reach of so many people living in an urban center. More than 17 million people, approximately 6% of the nation's total, live within a one hour drive of the park. The proximity of these resources to the urban population of the Los Angeles area is especially significant because open space of such high quality is so rare in heavily developed southern California.

Development Patterns

During the late 1880's, the Santa Monica Mountains were recognized as a resort mecca because of their isolation and serenity. Recreation and sports clubs, non-profit organizations and churches all built retreats. Small lot subdivisions deep within the mountains were created in the 1920's, and lots were given away as a promotion for subscribing to local papers and magazines. Large estates also began to appear in the 1920's and continue to be built today. As the motion picture industry brought fame to Southern California, "stars" moved to Santa Monica, Pacific Palisades, and Malibu, forming the nucleus of luxurious movie colonies.

In the 1980's, suburban development at the edge of the SMMNRA boundary grew at four times the rate of development in the rest of Los Angeles County. The proximity to the developed San Fernando Valley and the Westside, combined with scenic beauty and freedom from urban problems, made the area popular for suburban growth.

Over 2000 new single family residences, condominiums, and apartments were approved compared to the 1000 homes prescribed by the Los Angeles specific plan in use at the time. Several local municipalities incorporated during the development boon to gain more control over the rapid growth. Westlake Village (1981), Agoura Hills (1983), Calabasas (1991), and Malibu (1991) became independent cities. A *Los Angeles Times* investigative report published in 1998 found that homes in the new high-density developments were 2.4 times more likely to submit disaster relief claims, compared to homes built at the prescribed density (*Los Angeles Times*, 1998). The disasters included wildfires and floods during the 1990's and the 1994 Northridge earthquake.

In October, 2000, Los Angeles County adopted a new specific plan for the northern portion of the Santa Monica Mountains. New suburban-style development in and adjacent to the SMMNRA has mostly stopped, except for previously approved projects and the large 3,050-home Ahmanson Ranch project north of Calabasas in Ventura County. The majority of future development within the mountainous areas of the SMMNRA is expected to be single family residential homes.

II Climate and Geological Setting

Geologic Setting

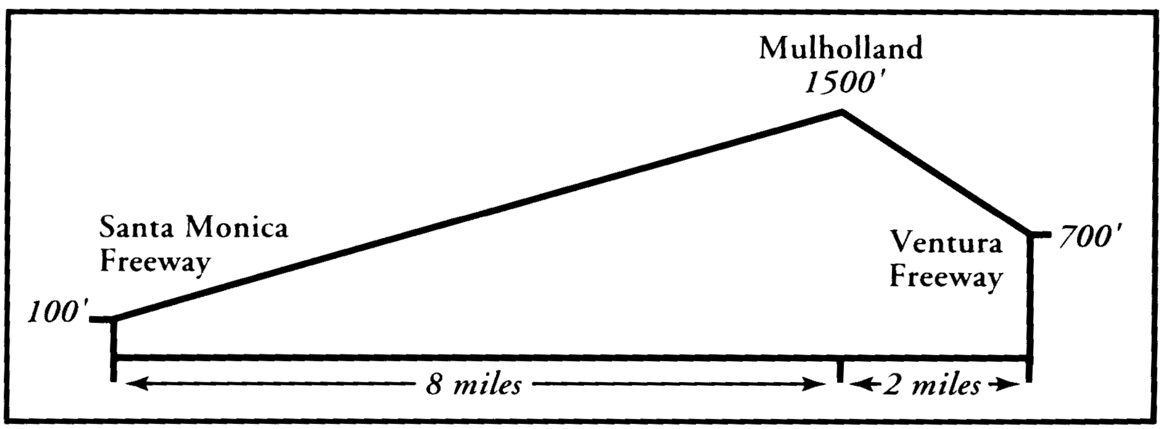
The Santa Monica Mountains, together with the four northern Channel Islands, are the southwesternmost of a series of east-west trending ranges that make up the Transverse Ranges of Southern California. They form a low range from 3 to 13 miles wide and extend from the Oxnard plain for approximately 45 miles eastward to the Los Angeles River. They are bordered by the Pacific Ocean and the Los Angeles basin on the south and the San Fernando Valley and the Simi Hills on the north. The range is bisected by Malibu Canyon, a deeply incised, antecedent drainage course that drains the north slopes of the Santa Monica Mountains and the southern slopes of the Simi Hills and discharges at Malibu Lagoon.

The Simi Hills parallel the Santa Monica Mountains on the north between the Oxnard plain and San Fernando Valley. They form a northeast trending ridge of approximately 15 miles in length at an average altitude of 2000 feet, eroded from resistant, thick bedded sandstone strata dipping north. They separate the San Fernando Valley on the southeast from the Simi Valley on the north, both at altitudes of 1200 feet.

The overall appearance of the Santa Monica Mountains is steep and rugged, with low valleys spaced intermittently along the north and south slopes. It includes coastal, valley, and mountain geomorphology. The western end of the mountains is igneous (extrusive volcanic). It shifts in the east to a sedimentary base, and the eastern end of the range contains metamorphic and older plutonic (intrusive) rocks. There are no natural lakes, but streams, springs, and seeps are common and widespread.

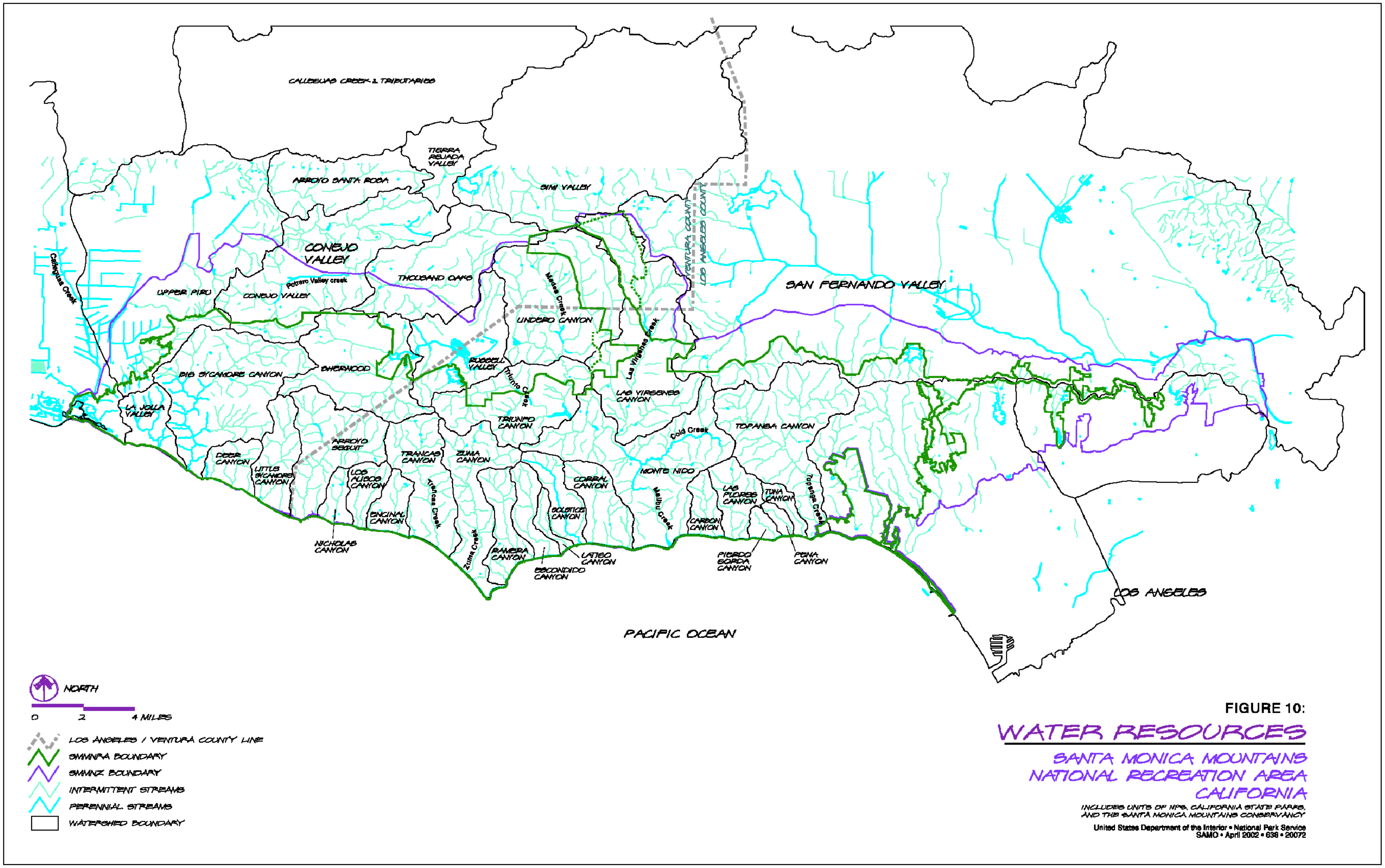
The elevation of the Santa Monica Mountains ranges from sea level to 3111 feet at Sandstone Peak, with a mean elevation of 1000 feet. The Santa Monica Mountains have a generally asymmetric profile (Figure 3-2) with long, V-shaped, deeply incised canyons that drain the south flank to sea level and short steep canyons on the north flank that descend to the higher base elevation of the San Fernando Valley and the Conejo Valley at about 1000 feet above sea level. The crest and the long ridges that extend southward from the crest are approximately 1500-2000 feet in elevation. Most of the summits along the crest are somewhat flattened, apparently remnants of an old Cenozoic erosion surface reduced to low relief prior to the latest series of uplift events (Dibblee, 1982). The steepest profile is situated near Griffith Park.

Figure 3-2 Profile of the Sepulveda Pass



The Santa Monica Mountain watersheds are illustrated in Figure 3-3, which shows the inland drainage area of the Malibu Creek watershed and the numerous, smaller south coastal slope watersheds.

Figure 3-3 Watersheds of the Santa Monica Mountains and Simi Hills

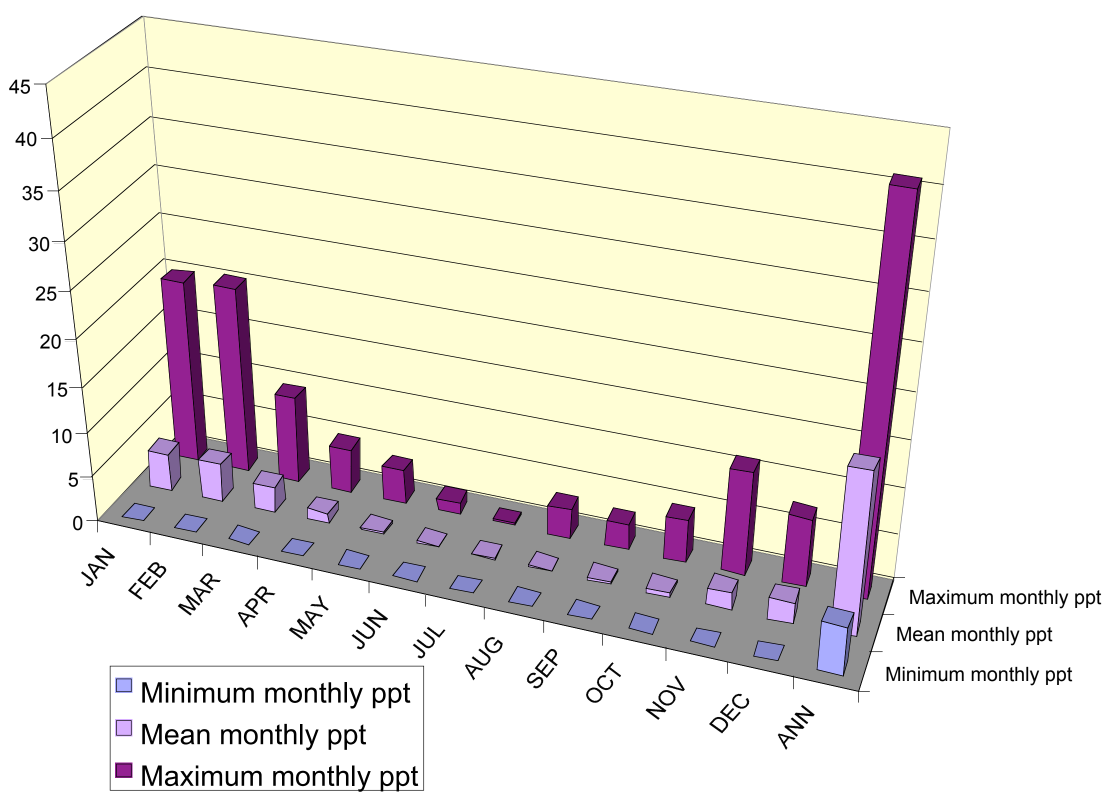


Rainfall

The SMMNRA has a Mediterranean-type climate. This climate type is characterized by mild, wet winters and hot, dry summers and occurs in only five locations throughout the world including parts of California, along the Mediterranean Sea, central Chile, parts of southwestern Western and South Australia, and the southwestern Cape region of South Africa.

On average, 86% of the Santa Monica Mountains rainfall occurs between November and March, with the majority (47%), concentrated in January and February from large storms that last for several days (Table 3-2, Figure 3-4). The dry season is considered to be from May-October. Virtually no significant rainfall (1%) occurs in June, July, or August. Evaporation exceeds precipitation from April to November (Keeley, 2000). The most significant feature of the regional rainfall pattern in addition to its unusual seasonal distribution, is its high degree of variability and unpredictability. Long periods may occur between storms in a single season and enormous variation exists among total rainfall amounts between years. At the UCLA weather station, the lowest rainfall year (1990, 5.26”) is approximately 1/3 the normal annual mean of 17”, while the highest rainfall year (1984, 41”) is almost 2 1/2 times the normal annual mean (Figure 3-4). Multiple years of low rainfall and extended drought punctuated by moderate to extremely wet years are not uncommon (Major, 1977). Within the SMMNRA additional variation in rainfall pattern occurs with respect to geographic location. While mean annual precipitation at the base of the Santa Monica Mountains in west Los Angeles is 17.4”/ year, it can be as much as 24-26” /year around the higher peaks (Huffman, 1998).

Figure 3-4 Annual Rainfall Patterns in the Santa Monica Mountains



Temperature

December-March are the coolest months and July-October the hottest months in the Santa Monica Mountains. Along the immediate coast both winter and summer temperature extremes are moderated, but as one moves inland to the interior canyons and valleys, temperatures become higher in summer and lower in winter. Mean monthly maximum summer temperatures can vary 15-20° F between UCLA at the base of the mountains on the coastal side and Canoga Park on the inland valley side (Raven et al, 1986, Figure 3-5). Winter nighttime temperatures average 10° C colder 4 km inland from the immediate coast (Boorse et al, 1998). Coastal sites rarely freeze, while inland sites often experience freezing between December-February in the range of –8° C to 12° C (Boorse et al, 1998). The frequency and duration of freezing events in the Santa Monica Mountains has been shown to affect chaparral species distributions and plant dieback (Boorse et al, 1998 and Langan et al, 1997).

Figure 3-5 Temperature Variation in the Santa Monica Mountains

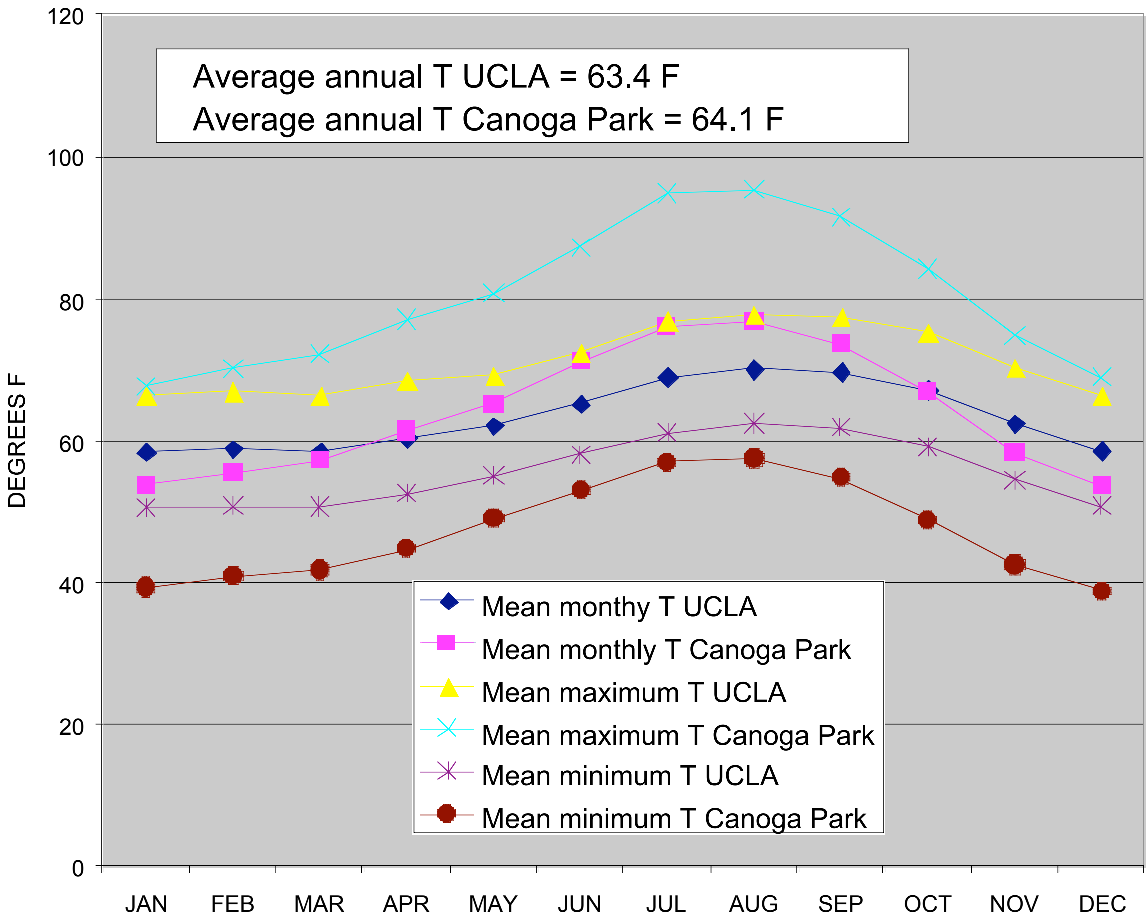


Table 3-2 Annual Temperature and Rainfall Patterns for the Santa Monica Mountains (UCLA, California)

Temperatures 1961-1990 (0F)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
Mean monthly T	58.4	58.9	58.5	60.4	62.1	65.2	69	70.1	69.7	67.2	62.4	58.6	63.4
Mean maximum T	66.2	66.9	66.4	68.4	69.1	72.3	76.8	77.8	77.4	75.2	70.3	66.2	71.1
Mean minimum T	50.5	50.8	50.6	52.5	55	58	61.1	62.4	61.8	59.1	54.5	50.8	55.6
Precipitation 1948-2001 (inches)	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**ANN**
Mean monthly ppt	4.02	4.22	2.78	1.15	0.26	0.08	0.02	0.11	0.23	0.41	1.86	2.29	17.54
Max. monthly ppt	20.11	20.51	9.52	4.86	3.7	1.29	0.25	3.23	2.81	4.76	11.3	7.46	41.09
Min. monthly ppt	0	0	0	0	0	0	0	0	0	0	0	0	5.26

Data from Western Regional Climate Center wrcc@dri.edu

Wind

Wind speeds vary in intensity and duration throughout the year within and adjacent to the Santa Monica Mountains. During summer days airflow is generally directed inland from the west, southwest, south, and southeast. At night, airflow patterns reverse and travel toward the ocean. The Santa Monica Mountains periodically experience extreme foehn-type winds locally called Santa Ana winds. These winds result from a regional, large scale weather pattern caused by the atmospheric pressure differential between a Great Basin high-pressure cell and a Pacific Coast trough of low pressure. Santa Ana winds average 20-30 mph and maximum gusts over 100 mph have been recorded. In the Santa Monica Mountains these winds are funneled through the north-south canyons and are therefore predominantly north or northeasterly winds.

Santa Ana winds have been identified as the primary driver of the wildfire regime in southern and central California shrublands (Keeley and Fotheringham, 2000; Moritz, 1997). Although Santa Ana winds can occur in any month, they predominate from September to December (Table 3-3). The major fires in the Santa Monica Mountains coincide with this peak of Santa Ana activity when vegetation is dry and temperatures high (Figure 3-6). A second small peak of Santa Ana wind activity occurs in March, but this is usually a time of cool temperatures and high moisture and does not create the severe fire conditions that occur during the fall Santa Ana winds.

Table 3-3 Santa Ana Wind Frequency and Duration by Month for the Angeles National Forest 1951-1960

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Average number of Santa Ana days per month	0.7	1	1.7	0.8	0.7	0.4	0.2	0	1.1	1.9	2.6	1.8
Average duration in days	1.7	1.9	2.5	1.8	1.4	4.5	2.5	0	4.4	4.5	5	3.7
Total number of Santa Ana days in month	1.2	1.9	4.3	1.5	1	1.8	0.5	0	4.8	8.6	13	6.6

Data from Biswell, Harold. 1989. Prescribed Burning in California Wildlands Vegetation Management, UC Press, Berkeley and Los Angeles, CA.

Fog

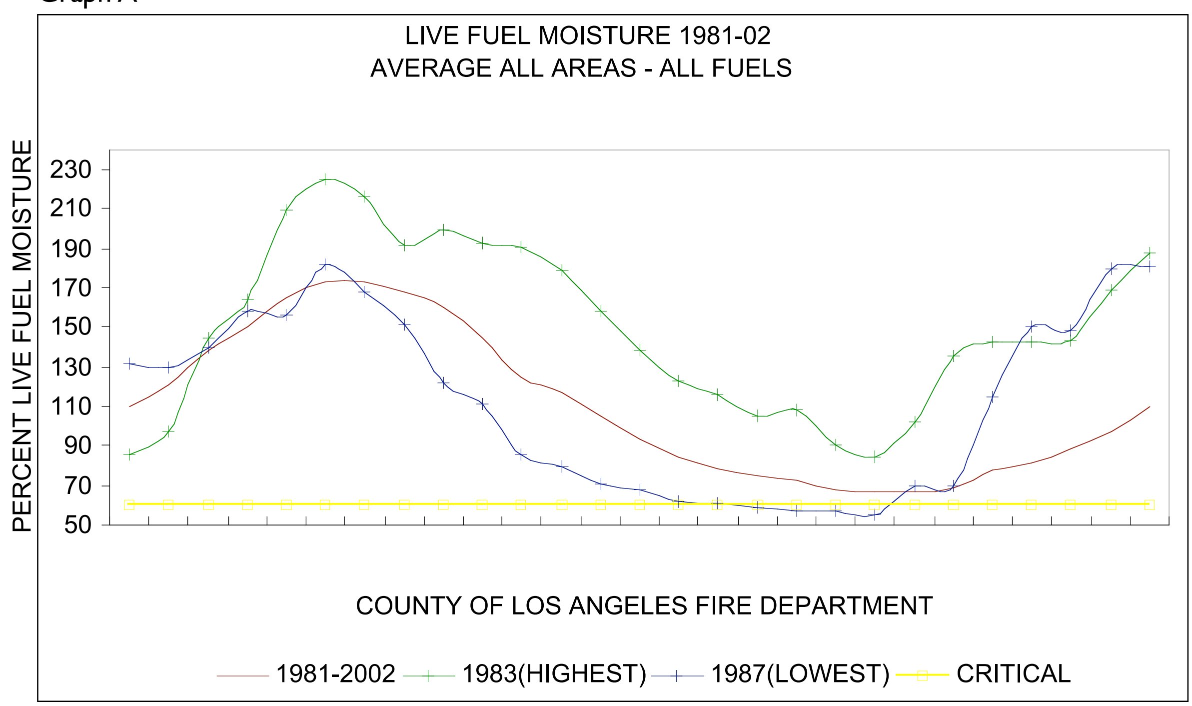
During the summer, a marine layer of fog is common along the coast during the morning hours, but dissipates by early afternoon. Early in the morning inland valleys may be fog-shrouded, but as temperatures increase, the fog dissipates until it crests the mountains and is vaporized or pushed out to sea. The coastal climate zone is classified as Mediterranean cool summer with fog in the Köppen system of climate classification, defined as areas with more than 30 days per year of dense fog. Inland of the coastal fog belt the climate is Mediterranean warm summer where the average temperature of the warmest month exceeds 71.6° F (22° C).

Climate effects on fuel moisture

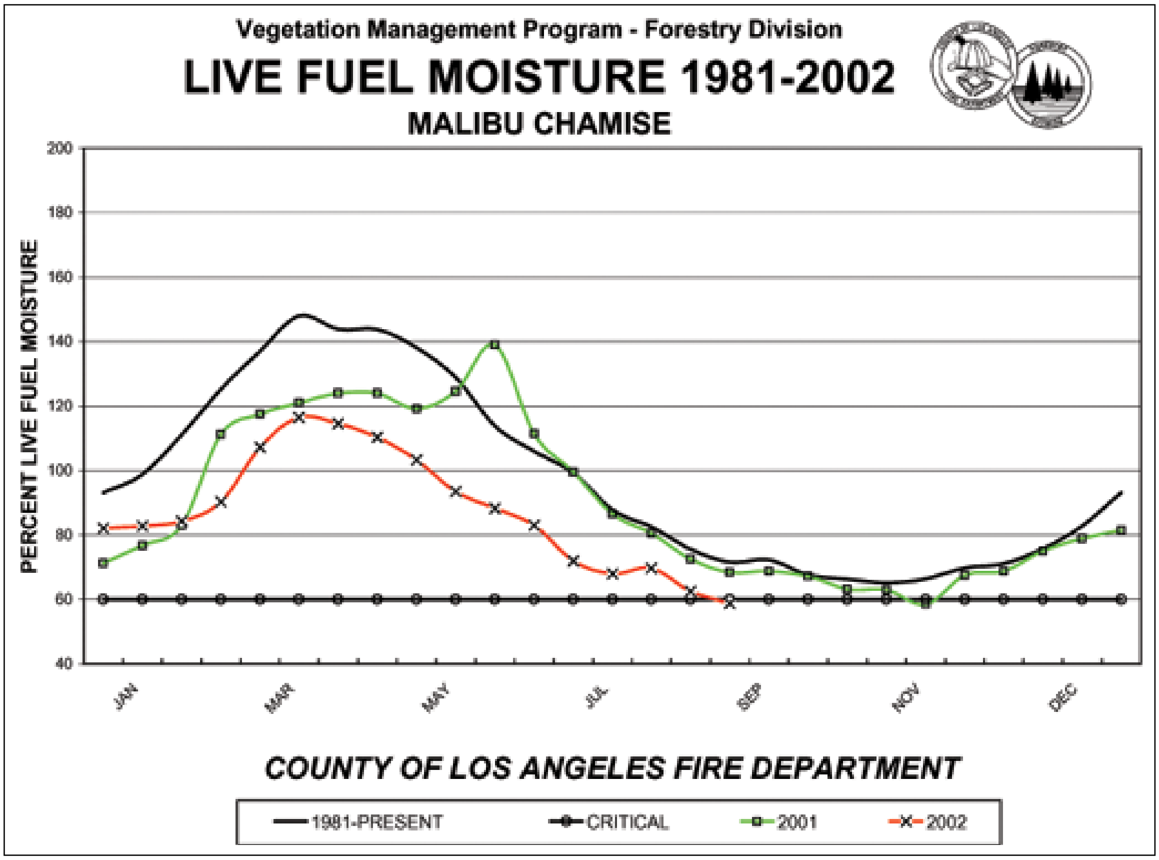
Live fuel moisture content is monitored by the Los Angeles County Fire Department as an indicator of the severity of the fire hazard. Sixty percent live fuel moisture is considered to be the critical point at which fire behavior in live fuels becomes the same as that observed in dead fuels, i.e., cellular moisture no longer significantly retards the heat transfer process. When rainfall is limited or occurs early in the season, the length of time during which vegetation is in a critical fuel condition is greatly extended (Figure 3-6). In high rainfall years, average fuel moisture never reaches the critical fuel moisture levels. In coastal Malibu, in most years, vegetation does not reach critical moisture levels. The 2002 season is a notable example of record low levels of live fuel moisture due to both the low amount of total rainfall and the absence of rainfall in the second half of the rainy season (Figure 3-6B).

Figure 3-6 Live Fuel Moisture Levels 1981-2002

Graph A



Graph B



Vegetation Management Program - Forestry Division
LIVE FUEL MOISTURE 1981-2002
MALIBU CHAMISE
PERCENT LIVE FUEL MOISTURE
200
180
160
140
120
100
80
60
40
JAN
MAR
MAY
JUL
SEP
NOV
DEC
COUNTY OF LOS ANGELES FIRE DEPARTMENT
1981-PRESENT
CRITICAL
2001
2002

III Fire Environment

The fire environment is the current fire regime based on fire history data from the 20th century. It includes analysis of fire type, seasonality of fire, ignition sources, fire intensity, fire frequency, fire return interval, and fire size.

Fire Type

Fires are typically either crown fires in shrubland vegetation types such as chaparral and coastal sage scrub or surface fires in grassland and oak savanna communities. Type converted shrublands with native shrubs growing in a non-native annual grassland matrix will experience cooler surface fires compared to high intensity canopy fires seen in normal shrublands.

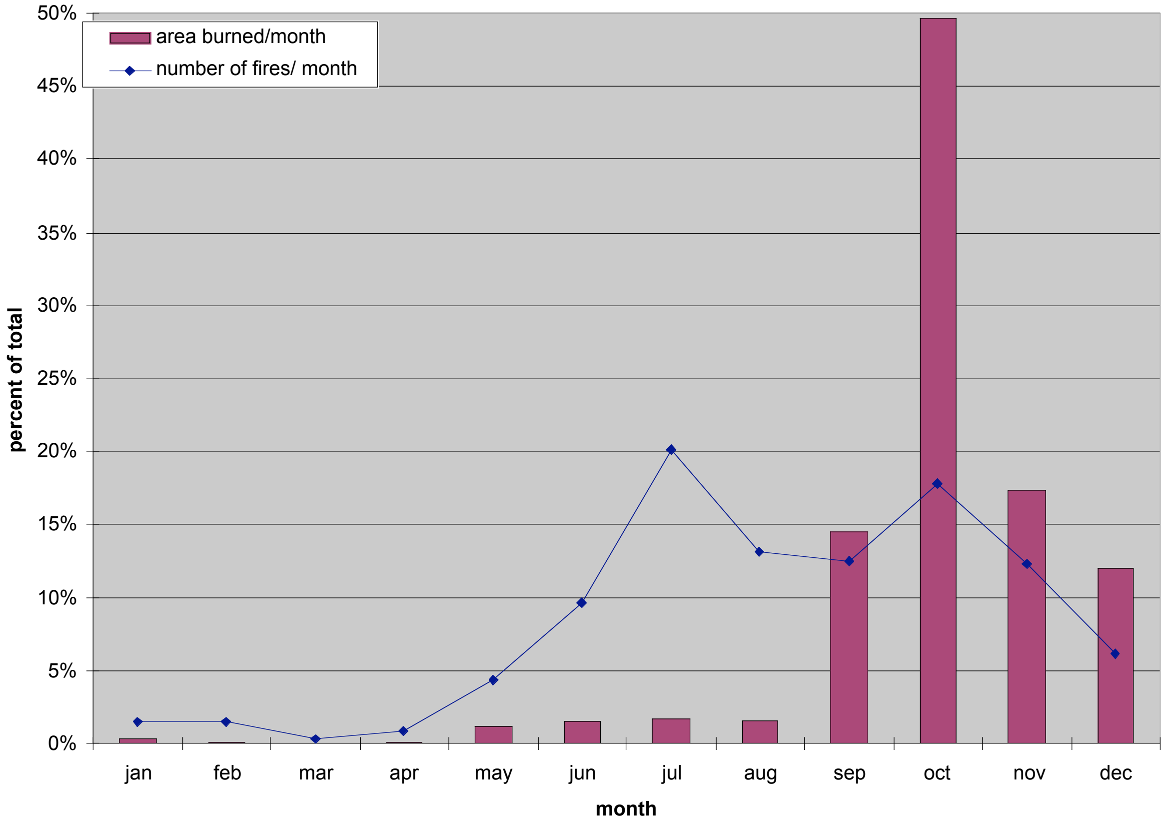
Rate of Spread

The rate of fire spread is determined by wind speed, topography (slope) and fuels. The largest and most destructive wildfires spread at extremely rapid rates which overwhelm the ability of firefighters to control them. The 1993 Old Topanga Fire, which started at 10:45 at the top of the Topanga watershed in the Old Topanga Canyon drainage, reached the Pacific Ocean at Sweetwater Canyon in 4 ¼ hours, ending by 3:00 pm. The 1978 Kanan fire crossed 13 miles to reach the coast in 2 hours (Davis, 1999).

Seasonality

Large fires account for the vast majority of the total area burned in the Santa Monica Mountains. Half of the area burned in the Santa Monica Mountains since 1925 burned in the month of October, while ninety percent burned between September and December (Figure 3-7). Although most of the area burned occurs in fall fires, there are a greater number of fires in the summer (Figure 3-7). The seasonal discrepancy is caused because large fires occur exclusively during extreme fire weather conditions of high temperatures, low humidity, and high winds, when wildfires spread rapidly and are highly resistant to control. Santa Ana winds, which are primary drivers of extreme fire weather in southern California, occur mostly in the fall.

Figure 3-7 Fire Frequency and Total Area Burned Per Month 1925-2000



Ignition sources

Analysis of all recorded fire starts in the Santa Monica Mountains from 1981-2003 shows that fire is overwhelmingly anthropogenic in origin. Of 161 recorded fire starts in 22 years, 96% were caused by human activity. Only six fires were ignited by lightning in two clusters of fire ignitions in 1984 and 1998. Lightning ignited fires burned less than .4% of the total area burned between 1981 and 2003. The largest lightning ignited fire burned 600 acres, while the others were .1-.2 acres in size. The two clusters of lightning starts were part of single weather events, the first of which occurred in June, 1984 and the other which occurred in early September, 1998 (Tables 3-4a, b).

The two major causes of fires that have burned large amounts of acreage in individual fires are arson and arcing power lines (Table 3-4a). Ninety percent of the total area burned in this time period has been started by arson (78%) and arcing power lines (12.5%). These types of ignitions generally occur under windy Santa Ana conditions when fires spread rapidly and control is difficult.

Fully one third of fire starts (4.9% of total area burned) are classified as unknown in origin. Eleven percent of fires (3.7% of total area burned) have been intentionally set as prescribed fires. The next most frequent causes of fires are arson, vehicle fires, powerlines, campfires or cooking fires, children lighting matches, mechanical/equipment, fireworks, lightning, dump/brush burning, and warming fires (Table 3-4b). Of these, only arson, power lines, lightning and three fires with unknown causes have ignited fires larger than 500 acres in size (the unknown starts burned 600, 2000, and 3700 acres). The vast majority of unintentionally started fires have been very small in size, between 0.1-10 acres (76%). The frequency of the larger size classes of fires from unintentional fire starts is: 11-100 acres (14%), 100-10,000 acres (7%), and >10,000 acres (3%). Several causes of frequent fire starts (5 or >) that have not caused any major fires (> 50 acres) for this time period are campfires, dump/brush pile burning, mechanical/equipment, and warming fires.

Table 3-4a Causes of Fire in the Santa Monica Mountains National Recreation Area 1981-2003 Ordered by Total Area Burned (acres)

Ignition Source of Fires	Number Area	Total Area	Mean Size	Maximum Range	Size
Arson	16	118,655.3	7,416.0	57,000.0	.1-57,000
Power line	10	18,980.9	1,898.1	13,190.0	.1-13,190
Unknown	50	7,378.1	147.6	3,700.0	.1-3,700
Resource burn	18	5,601.0	311.2	1,552.0	8-1,552
Lightning[1]	6	600.7	100.1	600.0	.1-600
Fireworks	7	279.1	39.9	278.0	.1-278
Children matches	8	112.9	14.1	80.0	.1-80
Vehicle	11	65.3	5.9	60.0	.1-60
Trash fire	2	20.2	10.1	20.0	.2-20
Aircraft fire	1	18.0	18.0	18.0	18.0
Warming fire	5	16.4	3.3	15.0	.1-15
Mechanical/equipment	7	12.6	1.8	5.0	.1-5
Camp/cooking fire	9	10.6	1.2	5.0	.1-5
Smoking	3	10.2	3.4	10.0	.1-10
Dump/brush pile burning	5	1.5	0.3	1.0	.1-1
Signal fire	1	1.0	1.0	1.0	1.0
Electrical short	1	0.1	0.1	0.1	0.1
Holdover	1	0.1	0.1	0.1	0.1
Total	**161**	**151,764**			

[1] Two clusters of lightning events in 1984 and 1998

Table 3-4b Causes of Fire in the Santa Monica Mountains National Recreation Area 1981-2003 Ordered by Fire Frequency

Ignition Source of Fires	Number Area	Total Area	Mean Size	Maximum Range	Size
Unknown	50	7,378.1	147.6	3,700.0	.1-3,700
Resource burn	18	5,601.0	311.2	1,552.0	8-1,552
Arson	16	118,655.3	7,416.0	57,000.0	.1-57,000
Vehicle	11	65.3	5.9	60.0	.1-60
Power line	10	18,980.9	1,898.1	13,190.0	.1-13,190
Camp/cooking fire	9	10.6	1.2	5.0	.1-5
Children matches	8	112.9	14.1	80.0	.1-80
Mechanical/equipment	7	12.6	1.8	5.0	.1-5
Fireworks	7	279.1	39.9	278.0	.1-278
Lightning[1]	6	600.7	100.1	600.0	.1-600
Dump/brush pile burning	5	1.5	0.3	1.0	.1-1
Warming fire	5	16.4	3.3	15.0	.1-15
Smoking	3	10.2	3.4	10.0	.1-10
Trash fire	2	20.2	10.1	20.0	.2-20
Aircraft fire	1	18.0	18.0	18.0	18.0
Signal fire	1	1.0	1.0	1.0	1.0
Electrical short	1	0.1	0.1	0.1	0.1
Holdover	1	0.1	0.1	0.1	0.1
Total	**161**	**151,764**			

[1] Two clusters of lightning events in 1984 and 1998

Fire Size

Summary statistics on fire size for the Santa Monica Mountains are presented in Table 3-5. The cumulative area burned is shown in Figure 3-8 and the size of individual fires and the year in which they burned is shown in Figure 3-9. The fire size distribution most closely fits a tapered Pareto distribution (Schoenberg, F.P., et al, 2002). Large fires account for the majority of the total area burned in the Santa Monica Mountains: the largest 1% of fires have burned 25% of the total burned area, the largest 5% have burned 71% of the total burned area, and the largest 10% have burned 86% of the total burned area (Table 3-5 and Figure 3-8).

Because the fire size distribution is so strongly skewed, calculating an average fire size has no meaning, i.e. it does not represent a "typical" fire size. The median fire size is 76 acres, i.e. half the fires are smaller and half the fires are larger (Table 3-5). Although the size distribution has remained largely stable over time, the trend in average fire size has declined very slightly from 1925 to the present (Figure 3-9; Schoenberg, F.P., et al, 2002).

Table 3-5 Summary Fire Statistics of the Santa Monica Mountains 1925-2001

Total area burned (acres)	569,474.2	
Total number fires recorded	368.0	
Mean fire size (acres)[1]	1,547.5	
Median fire size (acres)	76.3	
Min fire size recorded (acres)	0.3	
Max fire size recorded (acres)	43,043.1	
Area burned in largest 1% (n=4)	144,934.8	(25% of total)
Area burned in largest 5% (n=18)	402,189.3	(71% of total)
Area burned in largest 10% (n=37)	491,852.3	(86% of total)
Area burned in largest 25% (n=93)	550,902.4	(97% of total)

[1/] See text for qualification

Table 3-6 The 12 Largest Fires in the Santa Monica Mountains 1925-2000

YEAR	NAME	AREA (ACRES)
1982	Dayton Canyon	43,043.1
1993	Green Meadow	38,478.8
1956	Sherwood/ Zuma	35,217.5
1970	Wright	28,195.4
1935	Malibu	28,191.9
1978	Kanan	25,565.3
1970	Clampitt	24,650.4
1967	Devonshire-Parker	23,005.3
1949	Simi Hills	20,573.0
1930	Potrero No. 42	20,391.5
1958	(name unknown)	18,115.8
1993	Old Topanga Fire	16,462.5

Figure 3-8 Cumulative Total Area Burned 1925-2000

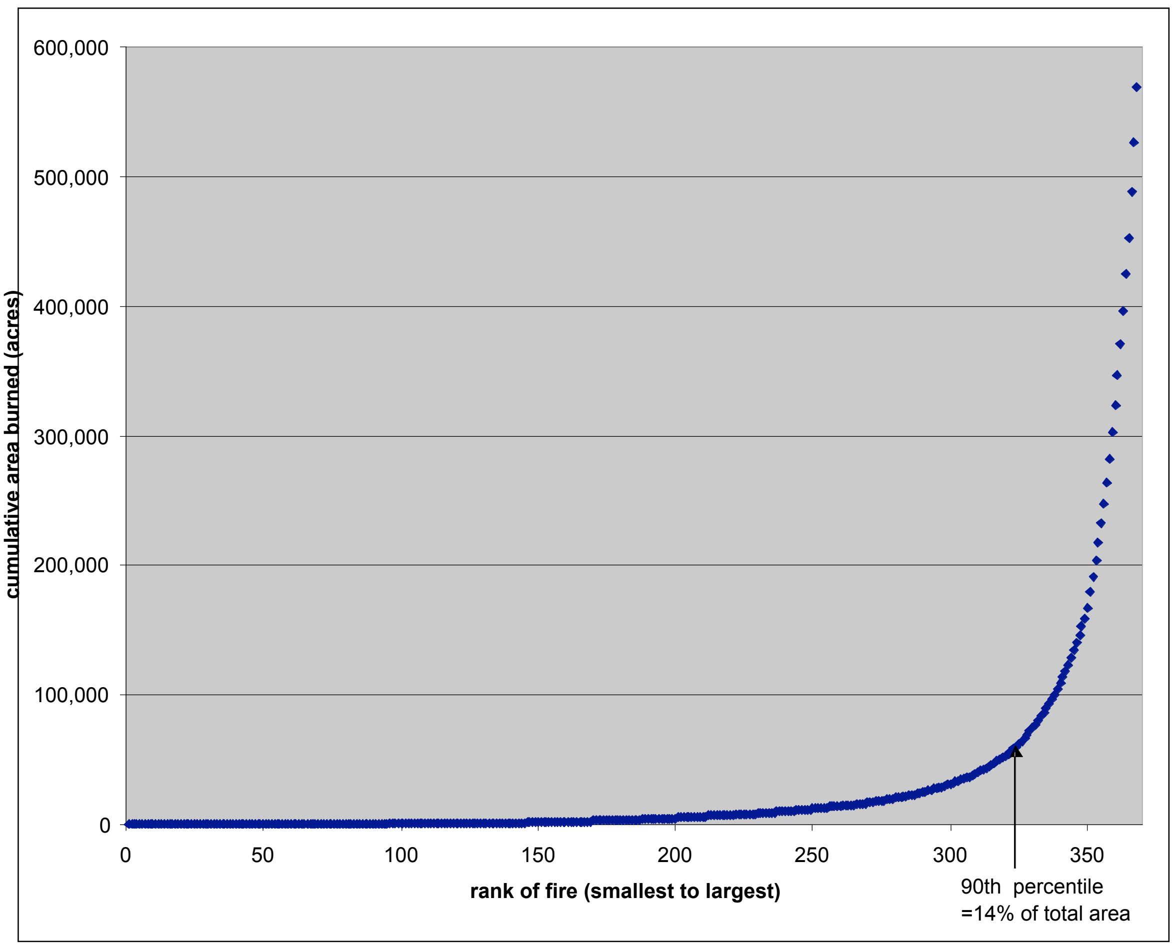
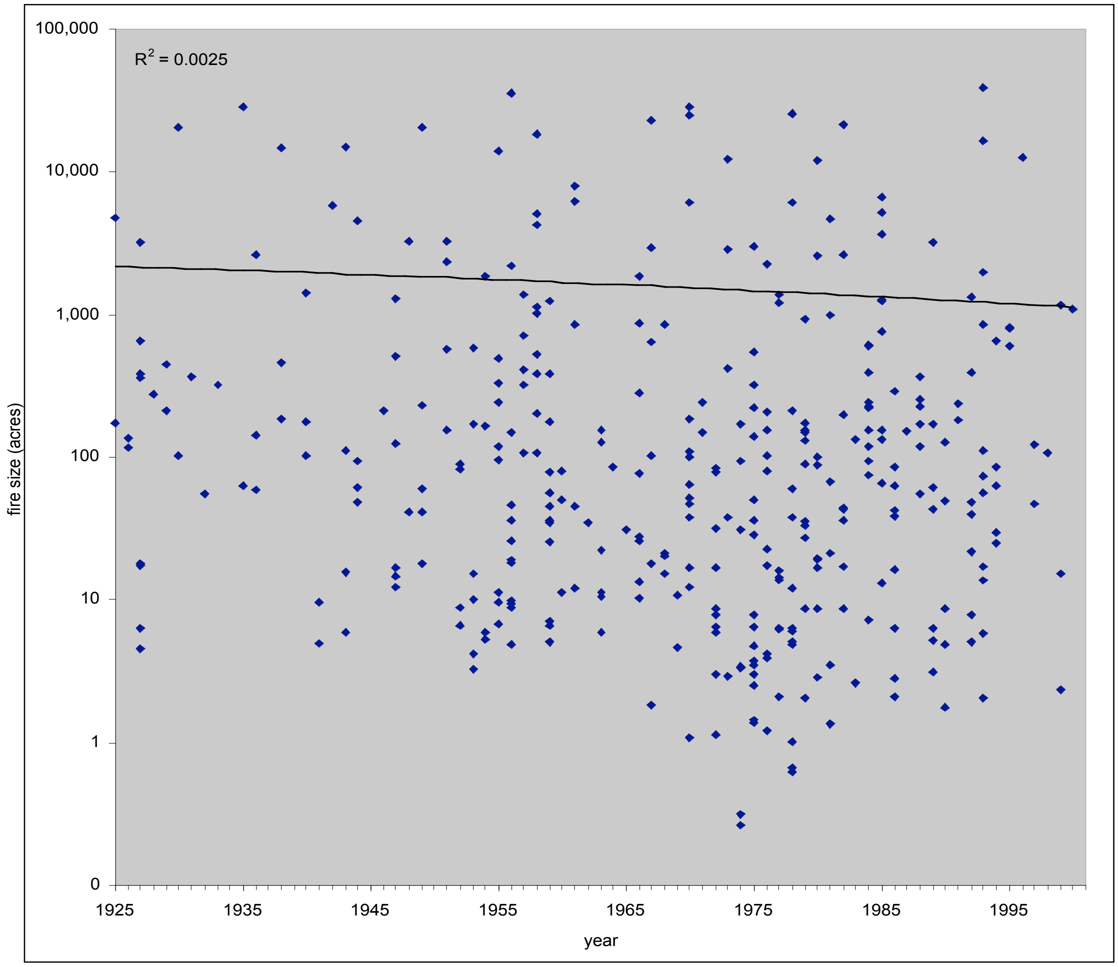


Figure 3-9 Size and Year of All Fires Recorded in the Santa Monica Mountains 1925-2000



Fire Intensity and Fire Severity

Fire Intensity

Fire intensity is the rate at which a fire produces thermal energy. It depends on the ratio live:dead fuels, fuel loading (wt/unit area), fuel density (wt/unit fuel volume), fuel surface:volume ratio (amount of fine fuels), packing ratio (fuel volume: fuel bed ratio), fuel bed porosity (spacing shrubs), fuel moisture, amount of volatile secondary compounds (ether extractives), temperature, and wind patterns.

Fire intensity can be expressed in a number of ways including radiant intensity, convective intensity, total fire intensity, reaction fire intensity, and fireline intensity (DeBano et al, 1998). Fireline intensity, one of the most commonly used measures of fire intensity, is defined as the product of the available heat of combustion per unit surface area and the rate of spread of fire. It is roughly related to flame length as

$$I = 300\ h^2$$

where, I = fireline intensity (kW/m) and h = flame height (m).

The range of fireline intensities in the Santa Monica Mountains can vary by 3 orders of magnitude, from 1.08×10^2 kW/m in grassland prescribed burns with flame heights of 0.6m (2 feet) to 2.7×10^5 kW/m in chaparral fires where flame lengths of 30 m (90 feet) were observed in the Old Topanga Fire (LA County, 1993).

Fire Severity

Fire severity is a measure of fire's effects on ecosystem properties including vegetation, soils, geology, water, wildlife, and society. Fire severity depends on the nature of the fuels available for burning, and fire behavior when these fuels are burned. Surface measurements of fire intensity may be poorly correlated with fire effects on ecosystem processes because several other factors may strongly influence fire duration, duff consumption and relative amounts of subsurface heating. Because one can rarely measure the actual energy release of a fire, the term fire intensity has relatively limited practical application. Resource managers are primarily interested in evaluating ecosystem responses to fire, thus measures of fire severity are the focus of most fire effects monitoring.

Because fire affects a variety of ecosystem components in complicated ways, fire severity cannot be expressed as a single quantitative measurement that relates to resource impact. Therefore relative magnitudes of fire impacts measured by a variety of resource and site-specific means are generally placed into broadly defined, discrete, nominal or ordinal classes of low, medium and high fire severity.

Several methods of assessing fire severity from ground-based measurements have been used on recent fires in southern California. Intense fires with long residence time generally consume available fuels more completely than less intense fires with shorter residence time. Keeley (1998) monitored fire severity of the 1993 fires on 90 sites in southern California. He employed two vegetation-based indices of fire severity based on measurements of unburned skeletons of shrubs. The first index was based on the diameter of the smallest remaining unburned twigs on shrub skeletons. The second index was based on the height above ground level of unburned twigs on shrub skeletons. These measures correlated with vegetation recovery at one year post-fire.

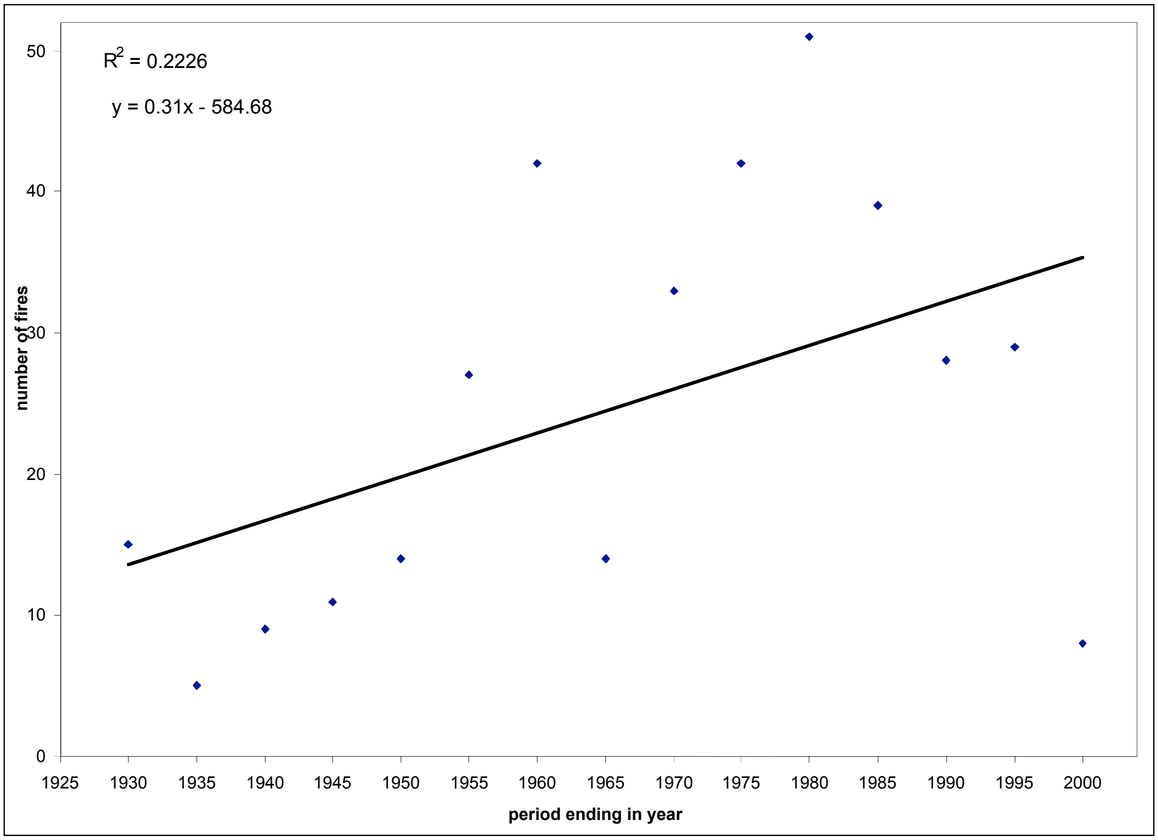
Intense fires and fires with long residence time often produce white ash while less intense fires and fires with short residence time often produce black ash. Relative amounts of black and white ash are often cited in fire reports as evidence of relative fire intensity in different areas. For example, an analysis of the 1996 Calabasas Fire (Radkte, 1996) referred to ash color while noting that grasslands burned with low intensity, 3-year old chaparral burned very lightly, 26-year old chaparral burned with greater fire intensity, while 14-year old chaparral burned with moderate intensity.

Remote sensing applications are increasingly promising sources of information about fire severity. Changes in vegetative cover, exposed soil, and relative amounts of different colored ash are readily discernable by aerial and space-based sensors. Recently fire severity and vegetation response after fires have been measured through multi-temporal analysis of AVIRIS imagery (Riano et al. 2002) and LANDSAT thematic mapper imagery (US Geological Service. 2002). When calibrated with georeferenced data from ground-based measures of fire severity, fire severity indices derived from remote sensing data may provide thematically accurate, high resolution, spatially explicit landscape scale characterizations of fire severity. Ongoing work at SMMNRA and on other public lands seeks to calibrate fire severity indices based on remote sensing data with ground-based data such as that collected by Keeley (1998a) to produce increasingly accurate and ecologically meaningful characterizations of fire effects on natural resources.

Fire Frequency and Fire Return Interval

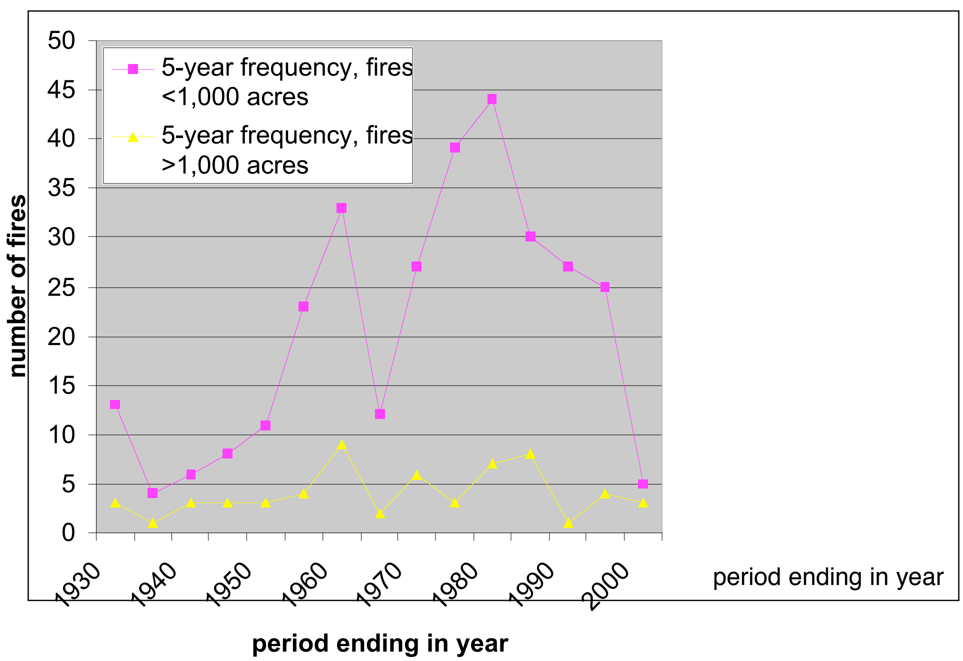
Fire frequency is the number of fires within a given area in a specific period of time; the fire return interval is the period of time between fires within a given area in a specific period of time. Fire frequency, the number of fires, has increased in the Santa Monica Mountains over the last 75 years (Figure 3-10). The total area burned per decade has also generally increased (Figure 3-12). Both statistics have shown a short term downward trend over the last decade, but the long term trend has been up for both measures. Fire frequency seems to show a cyclical pattern, with peaks around 1960 and 1980.

Figure 3-10 Fire Frequency by Five Year Periods



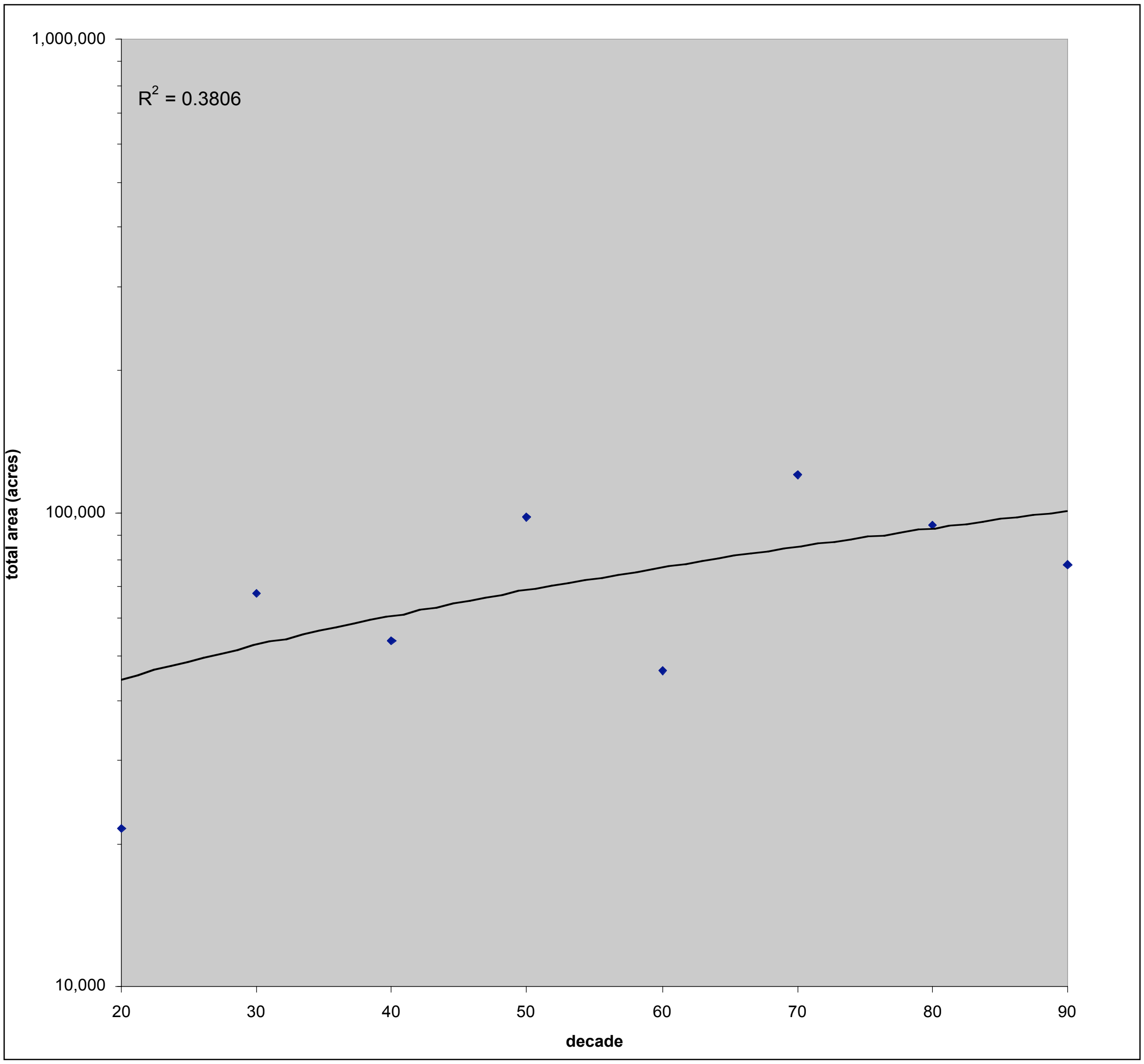
The frequency of small fires (area < 1,000 acres) has shown much greater change than the frequency of large fires (area > 1,000 acres) (Figure 3-11). The frequency of small fires hit a peak around 1980 and has dropped steadily since then.

Figure 3-11 Frequency of Large and Small Fires



The total area burned per decade has increased over the last 75 years (Figure 3-12). Because large fires make up the vast majority of all area burned, this measure is largely controlled by the frequency of large fires.

Figure 3-12 Total Area Burned by Decade



The average interfire interval for all natural areas in the Santa Monica Mountains from 1925 to 2001 is 32 years. This statistic expresses the average time between fires for any set of randomly determined locations in the area. The fire return interval at any particular location within the Santa Monica Mountains is widely variable because there are high fire frequency areas that have burned numerous times in the 76 years of record keeping and areas that have never burned in that period (Figure 3-13). This creates a complex mosaic of fire history across the landscape.

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fuel moisture (precipitation) have a more pronounced effect on burn area. Temperature effects appear to be constant above the threshold value of 21° C and burn area does not seem to be affected by either fuel moisture or precipitation (Schoenberg, F.P., et al, 2003).

It has been found that in the largest fires in chaparral shrublands (> 4000 ha), Santa Ana wind conditions are tightly coupled to the magnitude of the fire (Moritz, 1997). Below 4000 ha, wildfire size is not as tightly coupled to Santa Ana wind conditions, possibly due to the ability to better control fire spread under less extreme conditions, or because other environmental factors interact to affect fire behavior and suppression effectiveness.

Keeley has examined the influence of antecedent weather conditions on fire frequency and fire size (Keeley, 2002) in southern and central California. He found a weak positive correlation with the number of fires, but not the amount of area burned, with the amount of rainfall in the preceding year. More significantly, he found that for large fires (>5000 ha) drought conditions were not a necessary condition for fall fires, but that large fires that occurred outside of the fall season, i.e. summer and winter, occurred only under drought conditions.

Minimizing Wildland Fire Losses

The current data suggest a Santa Monica Mountains fire model of increased anthropogenic fire ignitions, where fires that begin under moderate environmental conditions are rapidly extinguished. Very large fires occur under extreme climactic conditions of low humidity and high wind and will burn through all vegetation age classes; the ability to control fires under these conditions is limited. Heavy fuel loads are an intrinsic characteristic of normal chaparral development and are not the result of fire suppression leading to unnatural, landscape level, fuel accumulations. The increased fire losses in the more recent decades is not due to fire suppression but due to the increased urbanization adjacent to wildlands with a vegetation type that will always be subject to recurrent large wildfires (Keeley and Fotheringham, 2001a; Keeley, 2002a).

Where development has been located in wildland areas subject to periodic large wildfires, property loss is due to three factors: 1) the speed of the initial fire, 2) extreme climactic conditions, and 3) lack of integrated structural resistance to fire (Coleman, 1995). The speed at which large fires spread means that fires at the wildland urban interface can do major damage before the majority of firefighting forces have been deployed. In the 1991 Oakland fire, for example, the majority of the losses occurred in the first two hours of the fire (Coleman, 1995). Computer simulations of fire spread under Santa Ana conditions in Brentwood (Sapsis, pers. comm.) and Topanga Canyon (DeMartino, 2000) show fire rapidly overtaking residential areas. Destructive wildfires with large structural losses such as the 1978 Kanan fire and the 1993 Old Topanga fire spread from the inland side of the range to the coast in 2 and 4 hours, respectively. In large fires where thousands of firefighters may ultimately be deployed, these resources are not available in the initial, critical hours of the fire. Under extreme climactic conditions of low humidity, high temperatures, and high wind in wildland areas of steep topography and dense chaparral, conventional firefighting techniques are severely limited. Finally, under the conditions of large wildfires, structures that lack defensible space or resistance to fire can not be safely protected.

Wildfire property losses can not be reduced by increasing the size of the mobilization efforts, changing the initial speed of the fire or by changing the climactic conditions or the local geography of existing structures. The only realistic protection for existing structures is to assure there is an adequate defensible space and structural integrity (Cohen, 2000; Cohen and Saveland, 1997). As important to reversing the trend of escalating losses is to locate new structures away from geographically indefensible locations.

Fire Management Strategies

Large wildfires in chaparral are not controlled by younger vegetation classes but are usually controlled by changes in weather, in conjunction with changes in fuel type or successful burnouts (Conard and Weiss, 1998). Analysis of the 1985 Wheeler fire (Dunn and Pirto, 1987 in Conard 1998) showed that 48% of the perimeter was contained by burnout, 14% due to change in fuel types, 9% due to obstructions, 11% due to weather changes (marine air), and 10% to direct attack. The fire burned around a 1-year old burn (1984) but 10-year old burns had no effect on the perimeter. Prescribed burning to create a mosaic of age classes is ineffective as a fire management technique due to the fire behavior of large fires and the practical and social constraints associated with sufficient prescribed burning to create a landscape level mosaic (Keeley et al, 1999; Conard and Weise, 1998).

A more current model of fire management in the chaparral is a strategic approach with three major objectives described by Conard and Weise, (1998):

1) To contain wildland fires strategically within easily defended borders.
2) To maintain a chaparral fire regime that fosters healthy, sustainable ecosystems in wildland areas.
3) To separate the wildland urban interface areas from natural fuel complexes, both to protect the wildland urban interface areas from wildland fires and to protect wildlands from fire starts in the wildland urban interface.

Fire Hazard Assessment

Fire management strategies need to be rigorously evaluated to identify values at risk from wildfire and to identify fire management strategies that will quantitatively reduce the fire hazard to those resources at risk.

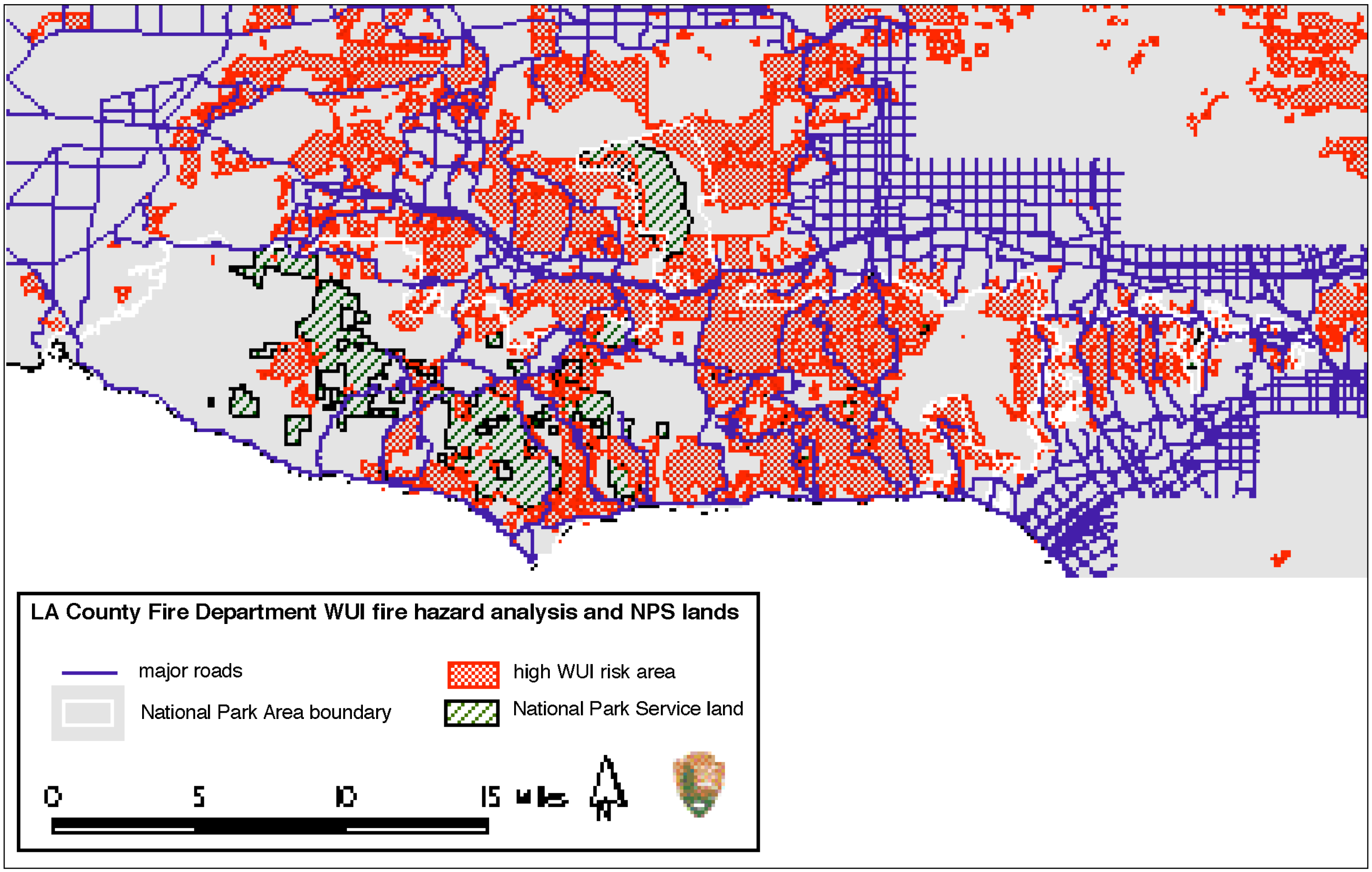
Estimating Risk

Social Values

Los Angeles County has identified communities at risk from fire hazard. Fire threatened wildland urban interface areas were identified by locating all development at densities greater than 1 unit/40 acres within 1.5 miles of areas that were a fire threat based on fuel hazard, probability of burning, and housing density. Using these criteria, the majority of the Santa Monica Mountains is considered to be a wildland urban interface area at high risk from wildland fires (Figure 3-17).

This figure illustrates that there are limited areas where structures are located adjacent to the NPS boundary. In these areas fire hazard is mitigated with mechanical fuel reduction treatments (Table 2-3, Figure 2-1).

Figure 3-17 Los Angeles County Wildland Urban Interface Hazard Map: Communities at Risk



Although the Los Angeles County risk map accurately shows that a large proportion of the Santa Monica Mountains is at risk from wildfire, it is not useful in identifying potential strategic fuel modification sites because of the lack of sensitivity and discrimination in the analysis.

To identify areas that might provide opportunities to either control fire spread (fuel modification strategies) or provide opportunities to contain the fire perimeter (fire containment strategies), a simple GIS-based analysis was developed from general principles of fire ecology and firefighting operations. The model is based on slope, vegetation type, vegetation age, and density of nearby structures (Figures 3-18 to 3-21).

A 30-meter digital elevation model was used to calculate slope steepness and identify areas where slopes are moderate enough that opportunities to control wildfire might exist. The thresholds selected were slopes less than 20 percent (optimum) and slopes between 20 to 40 percent (moderately feasible) (Figure 3-18). Slopes steeper than 40 percent limit tactical firefighting options such as mechanized equipment and make aerial resources, particularly air tankers, less effective.

The value of fuel modification to reduce fire hazard is strongly dependent on the type of vegetation and the age of the vegetation. Coastal sage scrub and grassland vegetation attain only relatively low levels of fuel loading at any age, and they exhibit very rapid rates of regrowth. Thus fuel modification projects in these vegetation types produce only relatively small and short-lived tactical benefits to firefighters. Chaparral has the highest fuel loads, generates the most intense and hazardous fire conditions, and takes longer to accumulate maximum fuel loads than other vegetation type in the Santa Monica Mountains. Because total standing biomass in chamise chaparral has been shown to level off after 35 years, chaparral over 35 years in age was selected as the vegetation criterion that would provide the greatest benefit on fire behavior from fuel modification. Fire history data was combined with the park's vegetation map to show where chaparral vegetation types (and non-native tree plantings) more than 35 years old occur (Figure 3-18). Chaparral is classified as a Type IV, 35 to 200 year infrequent replacement regime in the National Fire Plan's fire regime classification model. By using the 35-year standard, the minimum time for an appropriate fire return interval is applied to strategic fuels treatment proposals.

A simple overlay of these datasets produced a map of areas meeting all three criteria (Figure 3-18). These sites are areas that may be appropriate for strategic fuel modification projects. All other areas fail to meet at least one of the criteria defined as necessary to support successful strategic fuel modification projects. Overlaying a tract coverage shows how opportunities for strategic fuel modification are distributed among various land jurisdictions (Figure 3-19). The largest and most spatially contiguous areas where strategic fuel modifications might improve fire safety are located in the eastern half of the park, especially in the Topanga area (Figure 3-20).

Given the reality of limited funds to support fuels treatments and the narrow window of opportunity to conduct these treatments under favorable weather and air quality situations, a prioritization process for evaluating potential treatments is required. This prioritization process will include an evaluation of population density and the ability of a treatment to protect residences

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Fuel modification projects are meant to reduce the risk to communities from wildfire, but their effectiveness depends on when a wildfire occurs along the post-treatment timeline. This is illustrated with the arrows indicating the potential for a wildfire event at various points along the post-treatment timeline in Figure 3-22. When a wildfire occurs early in the post-treatment time line, the treatment will be most effective in providing protection and risk reduction. When a wildfire occurs late in the time line, the treatment will be minimally effective. The inherent conflict between fire hazard reduction and resource protection is that fuel treatments that are the most beneficial because of early wildfire also have the greatest potential to seriously degrade native plant communities. In this example, it is only in an intermediate post-treatment time frame that treatment is both effective at reducing risk and does not adversely impact the plant community. The time between median ecological risk and the time at which re-treatment is necessary is called the *hazard reduction window*. The hazard reduction window is the period of time during which a wildfire would be successfully modified by the treatment and which would not adversely affect the composition of the native plant community.

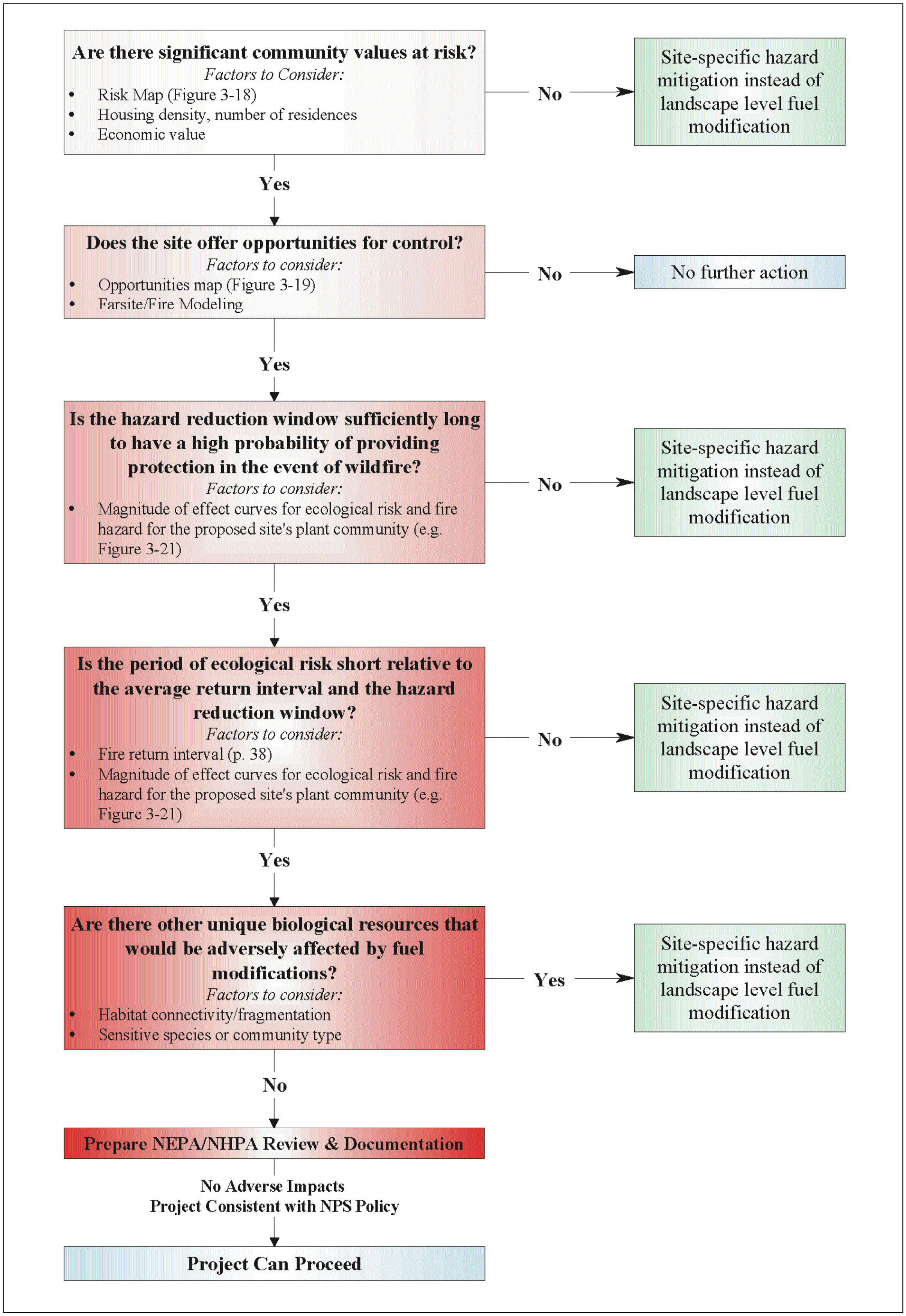
Obligate seeding species such as *Ceanothus megacarpus* are the most sensitive to short fire-return intervals i.e., they have the longest post-treatment period in which they are subject to ecological risk from fire return. Vegetation dominated by facultative seeder and obligate sprouter species will generally have a shorter post-treatment risk period.

Decision criteria for strategic fuel modification projects

Any fuel modification project proposed as mitigation for fire hazard must demonstrate the effectiveness of the treatment to reduce the fire risk to susceptible targets. The effectiveness of defensible space (Defensible Fuel Profile Zones) and hardening of structures to prevent wildfire structure loss at the urban-wildland interface is well understood (Cohen and Saveland, 1997). Modeling of large, landscape-scale fuel treatments show no difference in the total amount of acreage burned between no action and treatment scenarios, although there is some evidence of reduced acreage burned within targeted areas when spatial priorities for treatment locations are applied (Jones et al, 2003). Strategic fuels treatments are most effective for fire control under slope and fuel driven fire scenarios. During extreme weather events, such as sustained Santa Ana winds, treatment areas will normally burn. These treatments are effective at the shoulders of an extreme weather event as normal weather patterns return to the local fire area. This was observed during the October 1993 Kinneloa fire on the Angeles National Forest. The fire was contained on the western flank along the Mount Lowe fuelbreak as the Santa Ana winds slackened. This fuelbreak had been maintained with prescribed fire in February of 1993. The fire also held on the edge of the 1980 Pinecrest Fire with minimal suppression efforts applied to the 13-year old vegetation. However, during the height of the Santa Ana winds, the 10-month old Lake Avenue fuelbreak, which had also been treated in the February of 1993, burned over without substantially affecting fire behavior (Dave Kerr, pers obs).

Figures 3-18, 3-19, and 3-21 identify potential strategic fuel modification locations. Proposed strategic fuel modification projects will be evaluated according to the decision model shown in Figure 3-23. The decision model requires that changes in fire behavior and any associated enhanced protection of improvements be weighted against the ecological risk to resources from wildfire or cyclic fuels treatments. Changes to the fire environment will be analyzed with fire behavior models such as FARSITE and FlamMap to evaluate how the proposed action would affect both fire spread and fireline intensity. The ecological risk will be evaluated by the SMM-NRA Resource Management staff based on the best available data regarding vegetation response to disturbance. When landscape level treatments (i.e. those remote from the wildland interface) are found to be ineffective or overly damaging to resources, then site specific hazard mitigation treatments will be recommended in proximity to those values identified to be at risk. Project specific National Environmental Policy Act (NEPA) and National Historic Preservation Act (NHPA) compliance will be required on all proposed strategic fuels proposals. The required environmental review will provide the framework for balancing the environmental risk against the social benefits of the treatment.

Figure 3-23 Decision Model for Strategic Fuel Modification Projects



Risk Assessment and Public Safety

The NPS and other fire management agencies can assess relative wildfire hazard and may be able to identify actions or projects that would reduce the wildfire risk to life and property. Reducing wildfire risk does not eliminate the hazard, however. It is impossible in the fire climate of the Santa Monica Mountains to reduce risk to the extent that public safety can be guaranteed during an extreme wildfire event. Safety during a wildfire event is the responsibility of every individual. Residents need to understand the nature of the environment they live in, to anticipate the potential worst-case wildfire scenario, and to take the necessary preparation and preventative actions to protect themselves, their families, and their property.

IV Natural Resources

A1 Biological Resources – Vegetation and Fire Effects

Vegetation Types

In the Santa Monica Mountains, the distribution and composition of plant communities is determined mainly by the amount and seasonality of available water and sunlight. These factors, in turn, are influenced by elevation, aspect, slope, soil type, proximity to the ocean, and fire history. The history of local human land use is also a significant factor.

Munz (1974) identified seven plant communities in the Santa Monica Mountains: coastal strand, coastal salt marsh, freshwater marsh, coastal sage scrub, chaparral, valley grassland, and southern oak woodland. Raven et al. (1986) in the *Flora of the Santa Monica Mountains* include the following vegetation types: chaparral; coastal sage scrub; southern oak woodland; valley grassland; riparian woodland; intermittent stream bed; lake, pond and quiet stream aquatic; freshwater marsh; coastal strand; coastal salt marsh; marine meadow; and surfweed.

The most recent classification and vegetation map of the Santa Monica Mountains (Franklin, 1997) identifies 12 communities (Figure 3-24), which are derived from 26 vegetation associations identified by the California Natural Diversity Database classification system (Holland 1986).

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Various subcommunities, dominated by one or more species are described below.

Northern mixed chaparral (51.8% of total area) is found throughout the Santa Monica Mountains on moist, north facing slopes. It contains a diversity of large shrubs, including scrub oak (*Quercus berberidifolia*), greenbark or spiny ceanothus (*Ceanothus spinosus*), mountain mahogany (*Cercocarpus betuloides*), toyon (*Heteromeles arbutifolia*), hollyleaf redberry (*Rhamnus ilicifolia*), sugarbush (*Rhus ovata*), hollyleaf cherry (*Prunus ilicifolia*) and manzanita (*Arctostaphylos glauca and A. glandulosa*). Northern mixed chaparral, as currently mapped by the park, also includes Ceanothus dominated chaparral. Ceanothus chaparral primarily occurs on stable slopes above 1000 feet. On some coastal slopes, bigpod ceanothus (*Ceanothus megacarpus*) makes up over 50 percent of the vegetative cover, with greenbark *ceanothus* dominant in more mesic microsites. Hoary-leaved ceanothus (*Ceanothus crassifolius*) is the more common species on Boney Ridge, Tapia Park, and in the Simi Hills on dry slopes. Hairy-leaf ceanothus (*Ceanothus oliganthus*) occurs in more mesic sites in the Simi Hills and on the highest peaks in the Santa Monica Mountains. In addition to Ceanothus, associated species include chamise, black sage (*Salvia mellifera*), laurel sumac, and big berry manzanita (*Arctostaphylos glauca*), and other shrubs.

Red shank chaparral (0.54% of total area) is an unusual plant community that occurs in four distinct populations in California: southern San Luis Obispo County, Santa Monica Mountains, San Jacinto/Santa Rosa Mountains and northern Baja California. This community, characterized by red shank (*Adenostoma sparsifolium*), is well developed in the vicinity of Circle X Ranch, but may be found intermittently throughout the Santa Monica Mountains. Red shank chaparral is usually found on dry, fine–textured, well drained slopes and mesas at intermediate and higher elevations. In addition to red shank, it includes the following species: chamise (*Adenostoma fasciculatum*), sugarbush (*Rhus ovata*), ceanothus species (*Ceanothus megacarpus, Ceanothus crassifolius*) and occasionally wooly blue curls (*Trichostema lanatum*).

Chamise chaparral (2.01%) is found primarily on dry south-facing slopes or ridges. This community is overwhelmingly dominated (80 percent) by chamise, but may also contain black sage, sugarbush, bigpod ceanothus (*Ceanothus megacarpus*) and a variety of other species.

Post-fire herbaceous flora

One of the characteristic elements of chaparral and coastal sage vegetation, and an important contributor to the floristic diversity of the SMMNRA, is the abundant growth of a fire-ephemeral flora that occurs in the first 1-3 years following fire (Westman, 1979). This flora includes annuals, herbaceous perennials, vines, suffrutescent shrubs, and subshrubs. Herbs comprise more than three-fourths of the total post-fire number of species, area cover, and biomass (Keeley, 1981). Some of these species are pyrophyte endemics which persist in inter-fire years only in the seed bank. Other species, while more abundant following fire, may persist in canopy gaps, on disturbed sites or at xeric margins. When combined with resprouting shrubs and shrub seedlings, the diversity of post-fire chaparral approaches that of the high diversity mature fynbos and kwongan communities of South Africa and Australia (Cowling et al, 1996).

Fire Effects on Chaparral

The density and continuity of chaparral, its structural arrangement and chemical composition, in combination with extended drought of 6-8 months, make it one of the most volatile fuel types in the world (Schroeder, M.J et al., 1964). Physical characteristics of chaparral that promote intense wildfires include: 1) the spatial continuity of shrubs within stands that provide uniform fuel beds for the rapid and sustained spread of fire; 2) multiple stems which create high level of exposed surface to volume ratios in the above-ground biomass; and 3) high concentrations of volatile extractive compounds (resins, oils and turpenes) (Countryman and Philpot, 1970).

Chaparral fires are generally stand replacing fires that kill all above-ground vegetation. Chaparral is considered to be a highly resilient to fire disturbance because of the tendency to return rapidly to its pre-fire composition (Keeley, 2000). Hanes (1971) termed this phenomenon "auto-succession." There is little data on whether fine-scale changes in community composition occur as the result of differential fire-induced mortality of lignotubers and seeds or of differential seedling survival.

Despite its fire successional nature, chaparral in the Santa Monica Mountains does not require fire for ecological health. Old stands of chaparral are not "senescent," "senile," "decadent," or "trashy" (Keeley, 2000; Zedler and Zammit, 1989; Keeley, 1992a; Zedler, 1995); nor is there evidence of declining productivity in nearly century old stands (Keeley and Keeley, unpublished data in Keeley, 2000; Hubbard, 1986; Larigauderie et al, 1991); and chaparral is not successional to other vegetation types in the absence of fire.

Individual chaparral species have characteristic post-fire regeneration modes that are classified as either obligate seeders (mature plants killed by fire, recruitment from a soil seed bank), obligate sprouters (seeds killed by fire, regeneration by basal sprouting) and facultative seeder/sprouters (mixed seedling recruitment and vegetative resprouting). Among potentially resprouting species (both obligate sprouters and facultative sprouters), fire caused mortality of mature shrubs is variable. Some species have almost 100% vegetative resprouting (e.g. *Quercus berberidifolia*, *Heteromeles arbutifolia*, and *Malosma laurina*). Other species may suffer extensive mortality such as *Adenostoma* and *Ceanothus* sect. *Euceanothus*. Variation in survival may depend on fire intensity, fire frequency, soil moisture, plant size and physiological condition (Keeley, 2000). Variation in vegetative survival observed with different season of burn is likely due to differences in environmental and plant physiological status associated with seasonal changes.

Seedling density of obligate seeders and facultative seeder/sprouters is typically two orders of magnitude greater than pre-fire shrub density (Moreno and Oechel, 1992), with high seedling mortality in the first year(s) post-fire. Mortality has been correlated with both proximity and distance to resprouts, depending on the species; herbivory; and most importantly, differential drought tolerance (Keeley, 2000; Davis, 1989; Davis et al, 1998). Reproductive maturity requires 5-15 years before significant seed crops are produced and fires at more frequent interval can cause local population extinction (Zedler et al, 1983; Zedler, 1995; Fabritius and Davis, 1995). The life history of obligate seeders is classified as disturbance dependent, i.e., disturbance in the form of fire is required for seedling recruitment and population expansion. Obligate sprouters have a disturbance-free life history, i.e., seedling recruitment and population expansion occur in the fire-free interval. Obligate sprouters can persist in a high frequency fire environment through resprouting of mature individuals, but population expansion can occur only when fire-free intervals are long enough to allow new seedlings to reach a sufficient size to survive fire. Fire may still play an important role in this reproductive guild because recruitment to the canopy is rare and most saplings remain stunted under closed canopy conditions. Fire may therefore be required to make the transition from sapling to adult (Keeley, 1998b).

Chaparral species have correlated physiological traits associated with their reproductive mode. Disturbance dependent, obligate seeding species have shallower roots, higher tolerance of water stress, and greater post-fire seedling survivorship than disturbance-free, obligate sprouting species. The profound impact of physiological attributes on post-fire population structure is exemplified by *Malosma laurina*. This species vigorously resprouts after fire (100% regeneration) as well as produces an abundant post fire seedling crop. However, this extremely deep rooted species has very little tolerance to water stress and virtually all seedlings die (99%) in the first summer following a fire (Davis et al, 1998). Because of its physiology, this species, which is a facultative seeder/sprouter, behaves as a functional obligate resprouter and is regenerated after fire solely through vegetative resprouting.

The dramatic post-fire herb flora is a highly heterogeneous community. The density of herbaceous seedlings is very patchy, from microsites devoid of seedlings to sites of dense seedlings. Seedling density has been partly related to fire intensity where increased soil heating leads to increased seed mortality; areas with the highest seedling densities are in canopy gaps (F. Davis et al, 1989; Rice, 1993; Tyler, 1995 in Keeley, 2000). In 90 sites in southern California following the widespread 1993 fires, average 1st year post-fire cover was 72% (5-200%). Fire intensity (fire severity) was negatively correlated with species richness and total plant cover (Keeley, 1998a). This abundant natural post-fire cover argues against the need for any supplemental seeding for watershed rehabilitation in this community type.

Although annuals generally dominate the post-fire flora, herbaceous perennials and suffrutescents (e.g. *Lotus scoparius, Helianthemum scoparium, Eriophyllum confertiflorum*) are also an important component. In southern California as a whole, annuals are more dominant on better drained, hot, interior sites and herbaceous perennials are relatively more important on milder coastal sites with better water holding capacity (Keeley, 1998a).

High Fire Frequency and Vegetation Type Conversion

Although chaparral and coastal sage scrub may be adapted to the occurrence of fire, they are not adapted to all fire regimes. Where fires are frequent, non-native herbaceous annual vegetation has been observed to increase and replace shrublands (Vogl, 1977; Barro and Conard, 1987; Haidinger and Keeley, 1993; Beyers et al., 1994). This type of conversion, of shrubland to annual grassland, has been widely observed in California (Keeley, 1990; Minnich and Dezzani, 1998; Keeler-Wolf, 1995).

Natural variability in the fire regime interacts with varying regeneration strategies to maintain species diversity. However, if fire frequency exceeds that to which species are adapted, post-fire plant regeneration will be reduced and vegetation will respond negatively. Sensitivity to high fire frequencies varies with regeneration strategies. Non-sprouters show the greatest sensitivity to short fire return intervals and may be eliminated by a single premature burn. If an area is reburned before plants reach maturity and replenish seedbanks, local extinction can occur (Biswell, 1989; Zedler, 1995). Non-sprouting species need at least seven years to reach seed producing maturity (FMP, 1994) and if conditions are unfavorable, up to 15 years or longer (Biswell, 1989). Non-sprouting shrubs have only limited dispersal ability and once lost from an area, recolonization from other established populations can be extremely slow (Zedler and Zammit, 1989).

Obligate resprouters show greater resilience under short fire return intervals (Zedler et al., 1993; Fabritius and Davis, 2000), but nevertheless may be severely impacted by sustained high-frequency fire regimes. Successful germination and recruitment of new individuals is correlated with the cooler, moister, low light conditions and increased litter depth associated with the mature closed-canopy chaparral that develops over fire-free intervals of forty years or more (Lloret and Zedler, 1991; Keeley, 1992a & b; DeSimone, 1995). If a short-interval fire regime is maintained, senescent individuals and lignotubers that inevitably perish in fires will not be replaced, resulting in loss of resprouting populations over time (Zedler, 1995).

Although facultative seeders resprout after fire, mortality of lignotubers, particularly in chamise, can be very high if fire returns prematurely (Kay et al., 1958; Zedler et al., 1983; Haidinger and Keeley, 1993). Since a premature fire also kills seedlings that germinated in response to the previous fire, facultative seeders show only limited ability to persist under repeated disturbance.

Chaparral is generally believed to be adapted to fire return intervals ranging between 20 and 150 years, with average natural return intervals of 50 to 70 years (Minnich, 1983; Davis and Michaelson, 1995; Conard and Weise, 1998; Mensing et al., 1999). The return interval which eliminates shrublands is not clearly defined and is dependent on the interaction of fire with other environmental conditions and disturbances (Keeler-Wolf, 1995; Minnich and Dezzani, 1998). O'Leary (1995b) estimated that fire return intervals of 5 to 10 years can result in chaparral replacement by coastal sage scrub while others have found that this same interval will cause the replacement of coastal sage scrub with exotic grasslands (Timbrook et al., 1982; Minnich and Dezzani, 1998). However, even fire intervals of 20 years or longer may result in significant changes in stand structure (Parker, 1989).

Sensitivity of vegetation to short fire return intervals varies with species composition. A single premature fire can dramatically transform vegetation dominated by non-sprouters while vegetation dominated by resprouters may require years of sustained high frequency fires before a significant loss of shrubs occurs.

The introduction of herbaceous exotics, particularly annual grasses, has fundamentally altered the fire-ecology of southern California and plays a significant role in the conversion of shrublands to annual grasslands. Annual grasses increase fire frequency by changing the amount, distribution, and seasonal availability fuels for fire (Giessow, 1997). These grasses complete their life cycle early in summer season, but do not easily decompose (D'Antonio and Vitousek, 1992; O'Leary, 1995). This results in a large amount of fine standing dead fuel that supports very rapid rates of fire spread under a broader range of weather conditions than chaparral (Barro and Conard, 1987). Dry grasses have the lowest heat requirements for ignition and therefore have the longest fire season and highest fire frequency of any southern California vegetation type (Radtke, 1983). Most importantly, the capacity of exotic herbaceous fuels to burn is little influenced by previous fire history. Herbaceous fuel build-up is sufficient to support fire return intervals of one or two years, a cycle that will eliminate shrub communities (Zedler et al., 1983; Nadkarni and Odion, 1986; Minnich and Dezzani, 1998).

Although grass fires are less intense than shrub fires, they nevertheless consume native seedlings (Barro and Conard, 1987). If fire recurs at sufficiently short intervals or at inappropriate times, it can also kill resprouting shrubs (Murphy, 1968; Radtke, 1981; Zedler et al., 1983). At the same time, low-intensity grass fires can result in reduced seed mortality of opportunistic annuals (Moreno and Oechel, 1991a; Stephen Davis, personal communication). A positive-feedback cycle is thus initiated: fire opens the shrub canopy allowing establishment of exotic herbs, the presence of exotic herbs increases fire frequency, and frequent fires further increase the abundance of exotic herbs (Giessow, 1997). High fire frequency is perpetuated and ultimately there is type conversion of shrublands to exotic grasslands (Keeler-Wolf, 1995).

In addition to changing fire frequency, non-native grasses and forbs also alter nitrogen and organic matter cycles (Zink et al., 1995) and strongly compete for water and nutrients (Schultz et al., 1955; D'Antonio and Vitousek, 1992; O'Leary, 1995b; Eliason and Allen, 1997). Native annuals compete poorly and are quickly eliminated with the introduction of exotics (Keeley et al., 1981). Establishment of native shrub seedlings is also inhibited. Even in the absence of repeated fires, coastal sage and chaparral shrubs show only a limited ability to reinvade sites dominated by exotic annual grasses and forbs (Zedler and Zammit, 1989; Callaway and Davis, 1993; Haidinger and Keeley, 1993; Minnich and Dezzani, 1998).

Fire return intervals in the Santa Monica Mountains threaten the persistence of the shrublands that dominate the mountains (NPS, 1994). In some areas the average fire return time is as little as ten years and sequences of fires with intervals as short as two years have occurred. The problem is particularly acute in the extensive areas of mixed chaparral dominated by non-sprouting big-pod ceanothus, where vegetation can be dramatically and irreversibly altered by a single premature fire. These sustained high frequency fires also pose a long-term threat to areas dominated by resprouting species, as recruitment of new individuals is prevented. The problem is exacerbated by the widespread occurrence of exotic grasses and forbs which often occupy sites for several years after burning and can induce fire and nutrient feedback cycles that lead to vegetation-type conversion. Vegetation-type conversion in mixed chaparral has been documented in the Santa Monica Mountains after a series of fires in 1985, 1993 (FRI = 8 years), and 1996 (FRI = 3) (Fabritius and Davis, 2000).

Prescribed burning in a high fire-frequency environment
The addition of prescribed burning into an environment with an already high fire frequency increases both the potential for negative vegetation impacts and the possibility of vegetation-type conversion. Regardless of fuel reduction, shrublands can become fire prone within a few years following a burn, particularly when exotic annuals are present. Since it is impossible to predict the future post-burn fire regime (the time until an area burns again), an unknown risk is incurred whenever a prescribed burn is done. There is no guarantee that the next burn will not occur prematurely before non-sprouting species have matured and the seed bank has been replenished. In the mixed chaparral of the Santa Monica Mountains such a burn can have devastating impacts. The potential for repeated burning to induce vegetation-type conversion, even in areas dominated by resprouters, has long been known to range managers who used frequent burns to eliminate brush and improve grazing land (Kay et al., 1958; Murphy 1968).

In addition to the negative ecological effects resulting from increased fire frequency, prescribed burning in and of itself causes negative effects on shrublands that can significantly contribute to vegetation degradation and type-conversion. As the inability of shrublands to recover from excessively short fire return intervals illustrates, vegetation is not simply adapted to the occurrence of fire, but instead to a complex fire regime. In addition to fire frequency and length of the fire free interval, fire regime includes the type, intensity, and seasonality of fire. All of these components are interrelated and interact with environmental and biotic factors to influence post-fire vegetation response (Biswell, 1989). Variation in the fire regime helps to maintain biodiversity by favoring different species depending on their regeneration strategies. However, if fire occurs under conditions to which shrubland vegetation is not adapted, species will respond negatively and vegetation will become degraded (Parker, 1989).

In order to control fire intensity and spread, prescribed fires are set out-of-season when conditions are moister and cooler and fuel moisture levels are higher (Green, 1981). Since chaparral and coastal sage scrub are adapted to a regime of generally intense, dry-season fires, imposition of an artificial regime of low intensity cool-season fires by prescribed burning can produce undesirable ecological side effects and potentially severely damage vegetation. Out-of-season prescribed fires have been observed to kill resprouters and reduce resprouting from lignotubers without triggering germination of replacement seedlings. Desirable species may be lost and replaced with those more suited to the artificial fire regime (Malanson, 1985). Vegetation response is therefore similar to that which occurs under excessively short fire return intervals and can ultimately result in reduced species diversity and contribute to vegetation type-conversion.

Chaparral fires consume most above-ground plant parts and post-fire immigration of new propagules into burned areas is limited. Vegetation recovery is thus dependent on germination of soil-stored seeds and resprouts from lignotubers existing at the site (Hanes, 1971). Seeds of many dominant chaparral shrubs and fire-following herbs have high heat tolerance and require high-intensity fire to stimulate germination (Sampson, 1944; Sweeney, 1956; Keeley et al., 1985; Moreno and Oechel, 1994). Prescribed burning, which is necessarily conducted under conditions that produce low fire intensities, will select against these species and the long-term application of low intensity burns may result in significant shifts in vegetation composition. This is a particular problem in the mixed-chaparral of the Santa Monica Mountains where the dominant shrub big-pod ceanothus is killed by low intensity fires, but dependent on high intensity fires to stimulate germination. This has been recognized by local fire organizations and procedures have been attempted to create sufficient fire intensity during prescribed burns to assure adequate germination (Riggan et al., 1994; Stassforth 1997). Unfortunately, these techniques introduce new adverse ecological and aesthetic impacts.

Wildland fires are most common in late summer and autumn, when soils are dry. Prescribed fires are by necessity conducted earlier or later in the season under moister soil conditions (Green, 1981). Water decreases heat penetration into the soil, preventing necessary heating of hard-coated refractory seeds and reducing germination (Parker, 1987a,b; Riggan et al., 1988; Borchert and Odion, 1995). At the same time, many dormant seeds that readily take up moisture have reduced heat tolerance when wet and, although soil heating is reduced, show increased mortality (Sweeney, 1956; Parker, 1987; Rogers et al., 1989; NPS 1994).

Prescribed burns conducted in the winter or spring when plants are actively growing have the potential for negative impacts on post-fire resprouting. Chamise is particularly sensitive to out-of-season burning. Resprouting of chamise has been found to be significantly lower and lignotuber mortality higher when plants are cut or burned in spring rather than late summer (Jones and Laude, 1960; Doman, 1967; Rundel et al., 1987). This is attributed to reduced below-ground food reserves available for resprouting in the spring, when carbohydrates have shifted to the stems of actively growing plants. Spring and early summer fires can also be particularly damaging to coastal sage scrub, greatly reducing resprout vigor (O'Leary and Westman, 1988; O'Leary, 1995b).

Out of season prescribed fires, if done under low intensity prescriptions, can eliminate non-sprouters and reduce resprouting from lignotubers without triggering germination of replacement seedlings, creating gaps in the recovering vegetation canopy. At the same time low intensity burning can fail to produce sufficient heat to destroy seeds of opportunistic annuals (Moreno and Oechel, 1991a; Stephen Davis, personal communication). Prescribed burning thus creates conditions favorable to the introduction of exotic weeds which compete strongly with native herbaceous flora and increase the potential for initiation of a positive feedback cycle of increasing fire frequency and increasing numbers of weeds. The problem can be exacerbated when control lines are anchored at fuel breaks, trails or other access points that contain a high number of weeds (Giessow, 1997; Fabritius and Davis, manuscript in preparation). While utilizing existing vegetation breaks is greatly preferable to cutting new lines through vegetation, failure to clear these areas of exotics can result in enhanced post-burn weed ingression.

Coastal Sage Scrub (19.9% of total area)

The second most common vegetation type in the SMMNRA is coastal sage scrub. It occurs on drier sites and lower elevations than chaparral, especially on coastal, south-facing slopes of the Santa Monica Mountains and on inland areas of the Simi Hills. Coastal sage scrub grows on soils where moisture is available in the upper soil horizons only during the winter and summer growing seasons. These are usually coarse, shallow soils that overlie parent materials that retain little moisture and tend to be low in nutrients. Often occurring in recently eroded areas, this community plays an important role in soil stabilization. Many of its characteristic species produce soil-holding, fibrous shallow roots which do not penetrate to deeper soil layers.

The dominant species in this community are weakly ligneous subshrubs or suffrutescent herbs that have thin, drought deciduous leaves. Active growth occurs in the winter and spring when moisture is available. As soils dry out in summer, the drought deciduous species drop the larger winter leaves which are replaced with a few smaller axillary leaves called brachyblasts. In Salvia, leaves may curl up during summer drought, but then expand during the following growing season making these technically evergreen leaves (Gill and Mahall, 1986 in Keeley, 2000). Often terminal portions of stems die back. Photosynthesis rates are high during the winter and spring and greatly reduced during the summer and fall. Photosynthetic rates of coastal sage species during the growing season are twice that of evergreen schlerophylls (Harrison et al., 1971; Oechel et al., 1981; Poole, et al., 1981 in Keeley, 2000). The brachyblasts of drought deciduous shrubs can tolerate extremely low water potentials and these species are therefore true "drought-toleraters" versus "drought-avoiders" (Gill and Marshall, 1986 in Keeley, 2000).

Coastal sage scrub is a mixture of herbaceous, suffrutescent, and shrubby species that is less than 1.5 meters in height, often widely spaced between plants. The coastal sage scrub community has been referred to as "soft-chaparral" because the dominant species are frequently soft-leaved, grayish green, resinous aromatic shrubs. Characteristic plants include black and purple sage (*Salvia mellifera* and *Salvia leucophylla*), California sagebrush (*Artemisia californica*), coast goldenbush *(Isocoma menziesii*) and ashyleaf buckwheat (*Eriogonum cinereum*). Evergreen species that occur in coastal sage scrub include coyote brush (*Baccharis pilularis*), and the larger laurel sumac (*Malosma laurina*) or lemonadeberry (*Rhus integrifolia*) shrubs.

Related vegetation types in the SMMNRA include coastal sage scrub-chaparral transition types (0.6%), coastal cactus scrub (0.05%), and coastal bluff/dune scrub (1.39%).

Fire Effects on Coastal Sage Scrub

Coastal sage scrub is an important wildfire fuel in the Santa Monica Mountains. Fuelbed characteristics of coastal sage-scrub differ from mixed evergreen chaparral both in terms of fuel loading and fuel arrangement. Typical coastal sage-scrub species are weakly ligneous subshrubs which range in height from 0.5 m. to 1.5 m., and do not grow as densely per unit area as mixed chaparral, creating considerably less fuel loading and continuity of fuels (Westman, 1979; 1982; Keeley, 1982). The volatile oil concentrations of coastal sage-scrub species are considerably higher than mixed chaparral, which creates a higher reaction intensity per unit of fuel during pyrolysis. The more open canopy of coastal sage-scrub allows greater concentrations of grasses and herbaceous species to occupy the spaces between the shrubs than the closed canopy associated with dense stands of mixed chaparral (Westman, 1979 and 1982). This discontinuity in fuelbed characteristics is more susceptible to ignition, but has less intense fire behavior than in mature stands of mixed chaparral.

Coastal sage fires, like chaparral fires, are stand replacing fires that kill all above-ground vegetation. Both coastal sage and chaparral have abundant growth of a fire-ephemeral flora that occurs in the first years following fire. Most of the species comprising the post-fire herbaceous flora in coastal sage-scrub are common to post-fire chaparral sites (Keeley and Keeley, 1984; O'Leary, 1988; O'Leary and Westman, 1988).

Coastal sage scrub species regenerate as either facultative seeder/sprouters or as obligate resprouters that flower in the first year following fire and recruit seedlings in the second year post-fire (Keeley, 2000). Coastal sage shrubs are also capable of continuous seedling recruitment during fire-free intervals (O'Leary 1995), as well as regenerating their canopy from basal sprouts (Malanson and Westman, 1985).

Life form largely dictates the mode of post-fire regeneration. Herbaceous perennials are all obligate resprouters. Suffrutescents, with slightly woody bases above-ground are killed by fire and regenerate from an abundant seed bank e.g. Lotus scoparius and Helianthemum scoparium. Among the subshrubs, most are obligate resprouters. Two species, Eriogonum cinereum, Salvia apiana, form distinct basal burls (Keeley, 1998). Sprouting may be a necessary form of regeneration because it appears that the seeds of most coastal sage-scrub species are killed by the intense heat of a fire. However, three species of subshrubs are facultative seeders: Artemisia californica, Eriogonum fasciculatum, and Salvia mellifera. In these species first-year seedlings are common but resprouting is variable and there may be complete mortality at some sites. Post-fire resprouting in coastal sage scrub subshrubs tends to be more successful in younger, rather than in older shrubs and at coastal rather than inland sites (Keeley, 1998). Keeley (1998) has hypothesized that most coastal sage species are derived from herbaceous ancestors and that they lose ability to resprout as they become older and woodier.

Since a premature fire kills seedlings that germinated in response to the previous fire, facultative seeders show only limited ability to persist under repeated disturbance. Coastal sage shrub lignotubers may be similarly sensitive to short fire return intervals. However, mortality is highly variable and the ability of surviving shrubs to seed in the first year after fire appears to allow coastal sage scrub to persist under fire frequencies that eliminate chaparral (O'Leary, 1995b). Fire-recurrence intervals of 5-10 years may result in chaparral being replaced by coastal sage scrub (Keeley, 2000). More frequent fires , however will result in the transition of sage scrub to grassland that is dominated by non-native grasses (Haidinger and Keeley, 1993). Despite the apparently greater resilience of coastal sage scrub to short fire return intervals, vegetation conversion to annual grasses has been widely reported, particularly at drier inland locations (Callaway and Davis, 1993; Riggan, Franklin, et al., 1994; Minnich and Dezzani, 1998; O'Leary, 1995b). This may be due to interaction with other disturbance types such as grazing or drought or the ready establishment of exotic annual herbs which support high fire frequencies (Minnich and Dezzani, 1998). There is little data on whether fine-scale changes in community composition occur as the result of differential fire-frequency induced mortality of lignotubers, seedlings or seeds.

The presence of extensive stands of coastal sage scrub in the mountains is not inconsistent with a regime of infrequent large fires. The same characteristics that allow sage scrub to persist under moderate fire frequencies (continuous sprouting and seedling establishment) also allow perpetuation of sage scrub in the long-term absence of fire (Westman, 1981; Malanson and O'Leary, 1982; Malanson and Westman, 1985).

<u>Coast Live Oak Woodland (2.88% of total area)</u>

This community is found on the mountains' more mesic sites on north slopes, in shaded ravines, canyon bottoms and along streams and is characterized by coast live oak (*Quercus agrifolia*). Coast live oak woodland can vary from mostly closed canopy to a more open canopy on drier sites, often with a rich understory of vines, herbaceous perennials and shrubs. Frequent associates include hollyleaf redberry (*Rhamnus ilicifolia*), California bay laurel (*Umbellularia californica*), coffeeberry (*Rhamnus californica*) and poison oak (*Toxicodendron diversilobum*). When coast live oak woodland occurs along stream courses in conjunction with riparian tree species it is considered to be riparian woodland. It also intergrades with northern mixed chaparral on north facing slopes and as oak savanna with scattered individuals in grassland. Live oaks are evergreen with deep taproots that can reach to the water table.

Regeneration is occurring in stands of coast live oak, with seedlings and saplings present. Seedlings survive best at the canopy margins, bur recruitment from the seedling to the sapling stage is more likely in the gap between trees (Lawson, 1993).

Fire Effects on Coast Live Oak Woodlands

Coast live oak has a thick protective bark and is one of the most resistant of the oak species to damage by fire (Plumb, 1980). Coast live-oaks are obligate sprouters and depend on epicormic resprouts (new stems that grow from the trunk and main branches of the tree) for regeneration and recovery following a fire. Acorns are killed by fire so there is no postfire seedling recruitment. Coast live-oaks retain the capability to resprout from the basal stem and branches, even when foliage is entirely burned off and the trunk and branches are blackened. The resprouting capability of oak trees following fire is highly dependent upon the size of the basal stem as well as the height of the growing crown of the tree from the ground. Oak tree survival in one study found that 99% of the trees in the six (6) inch DBH size class and above survived an intense fire Plumb (1980). However, if fires are too frequent, resprouting may not be sufficient to re-establish the oaks (Plumb and McDonald, 1981).

The high productivity of the mesic oak woodland sites means that there is frequently a heavy fuel load growing in association with coast live oak that can lead to intense fires. Anecdotal information in the 1994 FMP (NPS, 1994) stated that the Dayton Canyon Fire of 1982 caused high mortality in oak woodlands with heavy fuel loading in areas that had not burned since the 1940's and 1950's. Recommendations to use prescribed fire to protect oaks from intense wildfire have been common (NPS, 1994; Plumb and McDonald, 1981, Green, 1979). However, post-fire monitoring of 90 oaks after the 1993 Old Topanga Fire had 96% survival after eight years and most trees had recovered 80% of their canopy cover within 2 years (Dagit, 1995 and in press). Even severely burned trees recovered normal canopy architecture as initial epicormic sprouting transformed over the years to typical terminal branching, with some epicormic sprouts growing into stout branches to replace scaffold branches lost in the fire. Basal stem sprouting, reported as a common response in mature trees burned in intense fires (Pavlik et al, 1991), was not observed except in a single top-killed tree (Dagit, 1995 and in press). This is consistent with a 1983 Forest Service report which found that coast live oak had a "unique ability to survive wildfire" even after being completely charred. In general, only trees smaller than 3" in diameter are killed in low intensity fires, and only trees less than 6" in diameter are killed in high intensity fires. Trees in the larger size classes sprout along their trunks and branches and prefire crowns are rejuvenated within 8-10 years (Plumb and Gomez, 1983).

Seedlings and saplings, as compared to mature trees, are top-killed and regenerate from basal sprouting (Pavlik et al, 1991; Tietje, 2001). However, seedling and sapling survival is not 100%. Mortality in burned Q. agrifolia seedlings is approximately 3 times the mortality of unburned seedlings (46% burned mortality vs. 15% unburned mortality), but season, degree of damage, preburn height. and site location all affect seedling survival. Sapling survival (height > 50 cm) was generally much higher than the smaller seedling size classes, but sapling burn mortality was 6 times that of unburned sapling mortality (3.6% burned vs. 0.6 % unburned mortality) (Lawson, 1993). The relative change in height is negative for burned seedlings and saplings in the first years after fire (Lawson, 1993). Fire therefore delays the progression of plants into larger size classes and has the potential to delay the recruitment of mature individuals into oak woodland populations.

An additional potential demographic impact of fire on coast live oak is the anecdotal report that acorn production may be delayed in severely burned trees (Borchert, 1999).

Riparian Woodland (1.69% of total area)

Riparian woodlands occur along canyon and valley bottoms with perennial or intermittent streams in nutrient rich soils, or within the drainage of steep slopes. The riparian community contains the greatest species diversity of all the plant communities in the Santa Monica Mountains (Rundel and Sturmer, 1998). Dominant species are coast live oak (*Quercus agrifolia*) and sycamore (*Platanus racemosa*); associates or locally dominant species include arroyo willow (Salix lasiolepsis), black willow (*Salix laevigata*), alder (*Alnus rhombifolia*), California black walnut (*Juglans californica*), Mexican elderberry (*Sambucus mexicana*), California bay laurel (*Umbellularia californica*) and mule fat (*Baccharis salicifolia*). Riparian woodland is a particularly important plant community because of its limited area (1.69%) and its extremely high plant and animal diversity.

Fire Effects on Riparian Woodlands

Although the conventional wisdom is that wildfires "jump over or stop along riparian corridors" (Rundel, 2000), fire severity in riparian woodlands can vary from scorched or lightly burned (foliage and smaller twigs partially to completely consumed, branches mostly intact) to heavily burned (all plant parts consumed, leaving some or no major trunks). There are no data on the frequency, severity, and physical fire properties of fires in riparian woodlands in the Santa Monica Mountains.

The effect of a severe fire on riparian woodlands in the north fork of the Matilija Creek in Ojai California was documented in a study following the July, 1985 Wheeler fire. Vegetative resprouting was variable among species: alders (7%), sycamores (83%) and oaks (70%). Regeneration was wholly by resprouting as no seedlings occurred in burned areas in the first year following the fire. Sprouting in alders was related to canyon location, sprouting in sycamores was related to height above the stream bed, and resprouting in oaks was related to size class (Davis et al., 1989). In addition to the direct effects of fire on riparian vegetation, the riparian zone is indirectly impacted by post-fire landslides and debris flows that alter the physical structure of the stream environment. In the same study, some alders and oak trees were also lost to flood flows and wind in the first years following the fire (Davis et al., 1989). Post-fire recovery in riparian zones is species specific: riparian zones dominated by sycamores and oaks may rapidly recover, while alders may re-establish much more slowly.

Arundo donax, an invasive woody grass of riparian areas, may alter the riparian fire regime and facilitate the further spread of Arundo. Dense stands of Arundo provide large amounts of flammable biomass that can promote intense fires that kill native plant species in the normally fire-resistant riparian zone. Arundo may spread more rapidly after fire by vigorous resprouting and dispersal of vegetative parts down stream (Rundel, 2000).

Walnut Woodland (0.17% of total area)

Stands of California walnut (*Juglans californica*) are most common in the foothills around the inland valleys of Ventura, Los Angeles and northern Orange Counties. In the SMMNRA they are located on the north slopes of the Santa Monica Mountains and in small stands in the Simi Hills on deep soils with high clay content (Quinn, 1990a). Walnut woodlands in the Santa Monica Mountains can occur with annual grassland understory, native herbaceous understory, coastal sage scrub understory, or intermixed with north slope chaparral and oak woodland.

Fire effects on Walnut Woodlands

Walnuts have thin bark and are top-killed by even moderate intensity fires. Burned trees resprout from the base and form a ring of new stems around the base of the fire-killed stem. Survivorship in mature trees is 100% but seeds are killed (Horton,1949). The critical size at which plants are large enough to resprout and survive fire is unknown. Older trees have a large woody platform below the soil surface which shields meristematic tissue from fire and from which new stems arise. Some of these platforms can be more than a meter across (Quinn, 1990a). Walnuts are frequently multistemmed in the Santa Monica Mountains, presumably from the high fire frequency (Witter, pers. obs.). Stand structure in a population in Brea Canyon indicates that recruitment is relatively infrequent and continuous. Trunk diameter is highly correlated with annual growth rings (r = .849) and can therefore be used to estimate the age of individuals and stands (Swanson, 1967 in Quinn, 1990a).

Valley Oak Savanna (0.68% of total area)

Endemic to California, valley oaks (*Quercus lobata*) occur on alluvial terraces of large valleys and on low rolling hills from Lake Shasta to northern Los Angeles County. They reach the southernmost extension of their range in Malibu Creek State Park. These trees, which are the largest oak species in North America, occur predominantly on deep alluvial soils within a narrow band of low elevation. Valley oaks can reach ages of 400-500+ years and may have trunks six or seven feet in diameter.

The valley oak savanna (also called the valley oak woodland) is typically a grassland savanna with widely spaced oaks. In the Santa Monica Mountains coast live oak (*Quarcus agrifolia*) can grow with valley oak on hillside areas. Tree density may increase along bottomland riparian corridors where valley oaks are an important component of the riparian woodland. Valley oaks are not especially drought tolerant and need available soil moisture for growth (Meyer, 2001). In many areas valley oak cover may be less than 10%, which can exclude it in rule-based classification systems as a separate community type and may limit recognition of the community's full distribution in inventory and mapping programs (Davis, 2000).

Over the last 150 years, valley oak savanna has succumbed to widespread agricultural and residential development that has focused on its prime habitat – alluvial valleys. Where valley oak savanna remains, it is vastly changed. It is believed that the original grasslands associated with valley oak savanna were native perennial bunch grasslands, comprised of dozens of species of native grasses and forbs. The native grasslands have been largely replaced by alien European annual grasses, although small relict patches of perennial grasslands exist. Today the valley oak woodland is the most seriously threatened of the foothill woodland types (Davis, 2000).

Valley oaks do not have a multi-age population structure, but are comprised primarily of very large trees with a few seedlings and saplings. Many years of failed seedling establishment mean that there are few young or medium aged trees in the valley oak savanna. Lack of sapling recruitment has been identified as the greatest problem facing valley oak survival (Griffin, 1971). Seedling establishment is affected by small mammal herbivory (gophers and ground squirrels) and soil moisture availability which may be caused by factors such as competition with annual grasses or lack of late season rainfall.

Characteristic grasses of the valley oak savanna include remnant stands of native purple needlegrass (*Nassella pulchra*), and widespread alien species such as wild oats (*Avena fatua*), ripgut brome (*Bromus diandrus*), and black mustard (*Brassica nigra*). Native wildflowers include mariposa lilies (*Calochortus catalinae*), blue dicks (*Dichelostemma capitatum*) and fiddleneck (*Amsinckia sp.*).

Fire Effects on Valley Oak Savanna

Mature valley oaks are fire resistant and able to survive grassland fires; seedlings and saplings are top-killed but can re-sprout from the root crown. Hot surface fires may kill large trees with extensive internal rot. Trees can survive moderate crown scorch from high intensity fires and regenerate with epicormic branch sprouts (Griffin, 1976). Acorns at the soil surface are killed by fire, but seeds deeply buried may germinate following fire (Carmen et al., 1987).

The literature reports a historic fire frequency of yearly burning in valley oak savanna (Vogl, 1977). However, in the coastal zone of California, including the Santa Monica Mountains, the fire frequency from natural lightning ignitions is extremely infrequent, on the order of decades (Keeley, 2002). During the approximately 10,000 years of Native American occupation "regular" burning of grasslands occurred at an unspecified frequency (Timbrook, 1982). Based on ethnographic reports of burning deergrass for basket materials (Shipek, 1989) and the time for plant recovery and community restoration of perennial grasses (Menke, 1992), fire frequencies on the order of 3-5 years are more likely (Anderson, 1996).

Because sapling recruitment is such a critical factor in restoration of age class structure to valley oak stands, prescribed fire should be used cautiously, because top-killing will delay recruitment to larger size classes. Special protective measures for prescribed burning might include hand clearing fuels from presently established seedlings and saplings until they can attain a fire resistant size class and removing heavy fuel loads from the base of existing large specimen or potentially susceptible trees.

Valley grassland and non-native annual grassland (3.85% of total area).

Valley grassland was recognized by Munz (1959) and occurs throughout California from sea level to 1500m (Keeley, 1990). Today, grasslands as open grassland or as the understory of oak savanna occupy approximately 10 million hectares in California (Heady et al, 1992). Valley grassland is often dominated by non-native annual grasses and is referred to as the California annual grassland. On localized sites, native perennial bunch grasses may dominate and such sites have been interpreted as remnants of the pristine valley grassland (Keeley, 1990). The transformation from native grassland to annual grassland occurred after settlement in 1769, predominately during the late 18th and early 19th century (Hendry, 1931). The composition and structure of California grasslands at the time of European settlement is not known. The current assumption is that moister (e.g. coastal) sites such as those in the Santa Monica Mountains were dominated by perennial bunch grasses, while drier (e.g. interior valley) sites were dominated by annual grasses, forbs, and possibly shrubs (Hamilton, 1997, Schiffman, 1997).

Many theories have been proposed to explain the decline of native grassland species and the dominance of non-native annual species. These include the introduction of livestock grazing, pre-adaptation of Mediterranean annuals to grazing, competitive superiority of annuals and greater annual seed output, an extended drought in the mid-1800's, and crop tillage (D'Antonio et al, in review). Crop agriculture is a strong predictor of the presence/absence of native perennial grasses (Stromberg and Griffen, 1996).

When disturbance factors believed to cause the decline of native grasslands are removed, native dominance often does not increase, even after decades (D'Antonio et al., in review). It is believed that the seedling stage of native perennials grasses is the most susceptible to competition from annuals and that this competition inhibits re-establishment of native species.

Not all annual grasslands were previously native perennial grasslands. Former shrublands, type converted by fire, grazing, or historic native American burning are now dominated by annual grasses. Native valley grassland habitat is distinguished from former type-converted shrubland habitat by the presence of deep soils (50-100 cm), with high clay content and no rocks, on level, north- or east-exposures compared to annual grasslands on rocky, shallow soils (10-30 cm), with little to no clay content and largely on south- or west-facing exposures (Keeley, 1990 and 1993).

Fire Effects on Grasslands

Grasslands are relatively low in fuel loading (approx. 1 –2 tons per acre) in relation to other fuel types, with contiguous fuel arrangement and high surface to volume ratios. The fuel characteristics of grasslands provide a ready source for fire ignition and promote very rapid fire spread (Anderson,1982). It was reported in the previous *Fire Management Plan* (NPS, 1994) that most large Santa Ana driven fires in the Santa Monica Mountains have ignition points in interior grasslands, but this needs to be critically analyzed and confirmed.

Type conversion of coastal sage and chaparral shrublands to annual grasslands shows that these exotic grasslands are well adapted to a high frequency, summer/fall fire regime and are one of the most fire resilient plant communities (Keeley, 1981).

The nature of the fire regime and the role of fire in the origin and distribution of native California grasslands is unknown. In the coastal zone of California, including the Santa Monica Mountains, the fire frequency from natural lightning ignitions is extremely infrequent, on the order of decades (Keeley, 2002a). During approximately 10,000 years of Native American occupation, "regular" burning of grasslands occurred at an unspecified frequency in order to increase the abundance or fecundity of geophytes, grasses and particular forbs (Blackburn and Anderson, 1993). Greenlee and Langenhem (1990) estimated a pre-contact fire frequency between 1 and 15 years.

Whatever its past history, fire remains a disturbance factor in the Santa Monica Mountains and most native grass species are tolerant of the current anthropogenic fire regime. Tolerance of fire, however, does not mean that fire is necessary for species persistence. Nassella pulchra, for example does not require fire or grazing to persist at a site (Bartolome and Gemmill, 1981; D'Antonio et al., in review).

Fire has the potential to aid restoration efforts in California grasslands by killing non-native seeds in the soil, killing adults prior to seed set, by stimulating the germination of native forbs and by providing a conducive seed bed for native grasses. Fire has a significant effect on annual grass abundance in the first year after fire, but will immediately revert to pre-fire levels in the second year post-fire without additional treatments (D'Antonio et al., in review). Fire therefore needs to be coupled with active restoration such as seeding or planting.

Coastal Salt Marsh (0.26% of total area)

Coastal salt marsh vegetation occurs in estuaries where semi-enclosed coastal waters have a free or periodic connection with the open ocean and within which sea water is measurably diluted with fresh water from inland drainages. Plants in this community are adapted to a high concentration of salt, very little wave action and oxygen-depleted soils. Succulence, usually associated with desert vegetation, is a common characteristic of plants growing in the coastal salt marsh. Some representative species include pickleweed (*Salicornia sp.*), dodder (*Cuscuta salina*), salt grass (*Distichlis spicata*), and sea blite (*Sueda californica*). Examples of this type of plant community in the Santa Monica Mountains can be found around Malibu and Mugu Lagoons.

From Santa Barbara to the border with Mexico, approximately 75-90% of the original salt marsh habitat is estimated to have been lost (Zedler, 1982; CDFG, 1983; California Coastal Commission, 1989). The isolation, rarity, and dramatic loss of coastal salt marsh habitat makes this community especially important in the Santa Monica Mountains.

Fire effects on coastal salt marsh
Not significant.

Coastal Strand (0.49%)

The coastal strand community occurs on sand along the immediate coast. Much of this community has been lost to development or recreational uses. The habitat is characterized by strong winds, salt spray, fog, intense solar radiation, drought conditions and an infertile, unstable substrate (sand). It extends from above the high tide zone landward in a narrow band along the southwest edge of the mountains, east of Point Mugu. Characteristic plants include sand verbena (*Abronia umbellata*), silver beachweed (*Ambrosia chamissonis*), saltbush (*Atriplex leucophylla*), beach morning glory (*Calystegia soldanella*) and the alien iceplant or hottentot fig (*Carpobrotus edulis*).

Fire Effects on coastal strand
Not significant.

Freshwater Ponds and Lakes (0.41% of total area)

In the Santa Monica Mountains, freshwater ponds and lakes are primarily artificial, but still form an important community type that provides valuable wildlife habitat. Among these are stock ponds at Rancho Sierra Vista, Rocky Oaks, Point Mugu, Palo Comado Canyon, Nicholas Flats, the Westlake and Las Virgenes Reservoirs, and Lakes Lindero and Sherwood, as well as many other small ponds. Characteristic plants include various cattails (*Typha spp.*), bulrushes (*Scirpus spp.*), rushes (*Juncus spp.*), and duckweed (*Lemna spp.*).

Fire effects on freshwater ponds and lakes
Not significant.

Rock Outcrops (0.25% of total area)

Innumerable cliffs and rock outcrops of sedimentary, metamorphic and volcanic origin dot the Santa Monica Mountains. These rocky outcrops support a unique flora including lichens, club moss (*Selaginella bigelovii*), rare species of *Dudleya*, *Hemizonii minthornii*, and *Leptodactylon californicum*. These areas also provide nest sites and perches for raptors and habitat for mammals such as the ringtail (*Bassariscus astutus*) and long-tailed weasel (*Mustela freneta*).

Fire effects on rock outcrops
Not significant.

Agriculture (0.15% of total area)

Agriculture occurs on a small portion of the SMMNRA. These include agricultural uses that have been retained on historical lowland agricultural areas (most of which have been converted to suburban development) and relatively new agricultural uses on upland mountain slopes for uses such as avocado orchards and vineyards.

Fire effects on agriculture
Not significant.

Suburban Development (12.7% of total area)

Suburban development occupies a significant portion of the SMMNRA. High density development is located along the freeway corridor of the 101 freeway. Scattered local communities and low density development is located throughout the mountains and contributes to habitat fragmentation and promotes the wildland urban interface fire hazard problem

IV Wildlife and Fire Effects

A2 Biological Resources – Wildlife and Fire Effects

Wildlife

The Santa Monica Mountains support an abundant wildlife community, which is reflective of the diversity of the vegetation within the SMMNRA boundary. More than 450 vertebrate species occur in the SMMNRA, including 50 mammals, 384 birds, and 36 reptiles and amphibians. The relatively intact wildlife populations of the mountains are especially impressive considering their proximity to one of the largest urban areas in the United States. The continued maintenance of wildlife populations in the Santa Monica Mountains is dependent on the ability of public and private land managers to ensure adequate habitat for the most sensitive species. As urban development within the mountains climbs up canyons, expands in pockets of low lying land, tops ridges, and encroaches on habitat adjacent to protected public land, it continues to remove and fragment habitat available to wildlife.

Mammals

Mule deer (*Odocoileus hemionus californicus*) are the largest herbivores in the Santa Monica Mountains. Mule deer are found throughout the mountains in a variety of habitats. Their distribution is limited by the fluctuating availability of water and vegetation.

Lagomorphs, or rabbits, are represented by three species, including the brush rabbit (*Sylvilagus bachmani*), Audubon's cottontail (*Sylvilagus audubonii*) and the black-tailed jackrabbit (*Lepus californicus*). Collectively these species inhabit brushy areas and especially meadows and grasslands.

Rodents comprise the final segment of the herbivorous mammals of the Santa Monica Mountains. Common species include the California ground squirrel (*Spermophilus beechyi beechyi*), fox squirrel (*Sciurus niger*), deer mouse (*Peromyscus maniculatus*), dusky-footed woodrat (*Neotoma fuscipes*), Pacific kangaroo rat (*Dipodomys agilis*), and the pocket mouse (*Perognathus californicus*).

The Santa Monica Mountains still contain mountain lions (*Puma concolor*), although their continued ability to survive in the face of large-scale habitat fragmentation and destruction is uncertain. It is likely that their persistence in the mountains depends upon their capability of dispersing to and from other habitat areas beyond the Santa Monica Mountains.
Other predators include bobcats (*Lynx rufus*), coyotes (*Canis latrans*), gray foxes (*Urocyon cinereoargenteus*), badgers (*Taxidea taxus*), ringtails (*Bassariscus astutus*), raccoons (*Procyon lotor*), spotted and striped skunks (*Mephitis mephitis* and *Spilogale putorius*), and long-tailed weasels (*Mustela frenata*). In general, the continued persistence of carnivores depends on their ability to survive amid increased development and on the extent to which these species can disperse between remaining open space areas.

Marine mammals that occur within the boundary of the SMMNRA are limited to harbor seals (*Phoca vitulina*), which breed in Mugu Lagoon. Other marine mammals that can be readily observed from within the boundary include migrating California gray whales (*Eschrichtius robustus*) and bottlenosed dolphins (*Tursiops truncatus*).

Birds

Located along the Pacific flyway, more than 384 species of birds (including vagrants) may be found in the mountains. In Malibu Lagoon alone, more than 262 species have been recorded. Of the total number of birds that may be found within the recreation area, approximately one-third, or 117, breed here. Thirteen of these breeders are raptors, which is an unusually high concentration. Sheer high cliffs of sedimentary and volcanic origin provide excellent nesting areas. Historically, California condors, bald eagles and peregrine falcons nested here. Currently, golden eagles (*Aquila chrysaetos*), red-tailed hawks (*Buteo jamaicensis*), red-shouldered hawks (*Buteo lineatus*), and Cooper's hawks (*Accipiter cooperii*) commonly nest here. Prairie falcons (*Falco mexicanus*), American kestrels (*Falco sparverius*), white-tailed kites (*Elanus leuairus*), barn owls (*Tyto alba*), great horned owls (*Bubo virginianus*), western screech owls (*Otus kennicottii*), burrowing owls (*Athene cunicularia*), short-eared owls (*Asio flammeus*) and turkey vultures (*Cathartes aura*) also nest within the recreation area.

Reptiles

Twenty-five species of reptiles inhabit the Santa Monica Mountains, including two turtle (one introduced), seven lizard and 16 snake species. The western pond turtle (*Clemmys marmorata pallida*) is considered rare. Common lizards include western fence lizards (*Sceloporus occidentalis longipes*), side-blotched lizards (*Uta stansburiana elegans*), and alligator lizards (*Elgaria multicarinata webbi*). The coastal horned lizard (*Phrynosoma coronatum frontale*), a California species of special concern, is also regularly observed in the recreation area. Common snakes include southern Pacific rattlesnakes (*Crotalus viridis helleri*), gopher snakes (*Pituophis melanoiecus annectens*), and California striped racers (*Masticophis lateralis lateralis*).

Very little information is available about the distribution and status of many reptile species in the SMMNRA. For example, two-striped garter snakes (*Thamnophis couchi hammondi*), coastal western whiptail lizards (*Cnemidophorus tigris multiscutatus*), San Diego mountain kingsnakes (*Lampropeltus zonata pulchra*), and silvery legless lizards (*Anniella pulchra pulchra*) are believed to be in decline or very rare.

Amphibians

The Santa Monica Mountains contain habitat for 11 species of amphibians, including five salamanders and six frogs or toads (two introduced). Two other species often listed for the Santa Monica Mountains, the arroyo toad (*Bufo microscaphus californicus*) and the western spadefoot toad (*Scaphiopus hammondi*), occur nearby but no historical records exist for their occurrence and no populations have been found in the SMMNRA. Until recently the California red-legged frog (*Rana aurora draytoni*) was considered extirpated. The garden slender salamander (*Batrachoseps nigriventris*) and Pacific treefrog (*Hyla regilla*) are relatively common. Other amphibian species may be suffering declines, including California newts (*Taricha torosa*), California treefrogs (*Hyla cadaverina*), and western toads (*Bufo boreas halophilus*) as a result of predation by exotic species, habitat loss, and likely other factors (e.g., U.V. radiation). In general, the decline of amphibian populations in the Santa Monica Mountains has become a priority concern.

Fish

A variety of native and introduced fish occur in the waters of the Santa Monica Mountains. Of significance are at least two spawning populations of the endangered steelhead trout (*Onchorynchus mykiss*) and one spawning population of Pacific lamprey (*Lampetra tridentata*), as well as several locations where California grunion (*Leuesthes tenuis)* spawn. Arroyo chub occur in the slow moving waters of Malibu Creek and a variety of introduced fish, such as largemouth bass, bluegill, and goldfish, occur in freshwater streams up and downstream from recreational lakes and golf course such as Malibu Lake and the Malibu Country Club.

The lagoons provide habitat to a number of migratory water birds, and support one of the southernmost steelhead trout runs in the U.S. Besides the reintroduced tidewater goby, and resident steelhead, native fish in Malibu Lagoon include killifish (*Fundulus parvipinnis*), arrow goby (*Clevelandia ios*), staghorn sculpin (*Leptocottus armatus*), long-jawed mudsucker (*Gillichthys mirabilis*), opaleye (*Girella nigricans*), topsmelt (*Atherinops affinis*), diamond turbot (*Hypsopsetta guttulata*), northern anchovy (Engraulis mordax), California halibut (*Paralichthys californicus*), Pacific lamprey (*Lampetra tridentata*), queenfish (*Seriphus politus*), bay pipefish (*Syngnathus leptohynchus*), starry flounder (*Platichthys stellatus*), kelpfish (*Gibbonsia mon - terivensis*), and serranid (*Paralabrax sp.*) (Manion, 1993; Manion and Dillingham, 1989).

Insects

Information on insects and their relationships to other organisms in the Santa Monica Mountains is very limited. The diversity and abundance of these organisms is certainly quite large. Aside from references by Emmel and Emmel (1973) and Hogue (1974, 1993), very little comprehensive information on insects exists for the mountains. Partial surveys and species lists exist from various sources (e.g. Resource Conservation District of the Santa Monica Mountains, docents from Charmlee County Park, etc.). However, few, if any, systematic surveys have been completed.

General Fire Effects on Wildlife

The effects of fire on wildlife can be divided into two broad categories: direct effects that occur during the fire and later, indirect effects that occur following the fire (Quinn, 1979; Lyon et al., 1978; Barro and Conard, 1991; Patton, 1992). Both effects can significantly influence the long-term ecological dynamics of a community by directly altering local wildlife population levels and by dramatically changing habitats in areas that have burned. A number of published studies exist which address various aspects of these issues, many based on research conducted in southern California.

Direct Effects on Wildlife During a Fire

Because so many fires happen unexpectedly, detailed, quantitative studies of the direct effects of fire on wildlife are somewhat limited, particularly for large-scale wildfires. In addition, most research in this area has focused on small animals, including small mammals, reptiles, and some birds. Despite these limitations, a substantial amount is known about how fires directly affect local wildlife species.

For relatively small vertebrates, fires can and do cause substantial mortality, and can result in local declines or extinctions in areas following fire (Wirtz, 1974; McClure, 1981; Peek, 1986; Patton, 1992). This is particularly true for species which live above ground and tend to retreat to brush or nests for safety — species such as brush rabbits, woodrats, some reptiles, and sedentary chaparral birds. For example, dusky-footed woodrats (*Neotoma fuscipes*) can be heavily impacted by fire. This species, which inhabits thick chaparral vegetation, has been observed to become disoriented during fires, haphazardly retreating to woody nests or to roads and trails to escape oncoming flames (Quinn, 1979). Of course, these strategies are often ineffective and may be fatal, resulting in extensive woodrat mortality within a burned area. In addition, fires during breeding season may cause nestling and fledgling mortality.

Despite these potential local population impacts for small vertebrates, most researchers agree that at the regional population level, mortality effects are very small if not negligible (Wirtz, 1977; Quinn, 1979; Patton, 1992). This is because the species which are most affected are able to rapidly re-colonize burned areas through recruitment and immigration from surrounding areas as the habitat recovers following the fire. Thus, while local extinctions may occur for some species, at the landscape level these impacts are generally regarded as insignificant.

Many small animals are able to survive fire by burrowing or seeking refuge in unburned patches or other safe areas (e.g., within rock outcrops). For example, in underground burrows or under rocks, survival has been documented for small mammals and reptiles just 10 to 20 cm below the soil surface (Howard et al., 1959; Lawrence, 1966; Quinn, 1990). In these locations, animals can be insulated from surface heat as high as 500° C (Wirtz, 1977). Lawrence (1966) conducted field experiments which demonstrated that, for rodents, survival can occur within burrows because vapor pressures remain low enough to facilitate evaporative cooling from lung surfaces. In another study, 75% of Heermann's kangaroo rats (*Dipodomys heermanni*) were estimated to survive within an experimental burn by retreating to their burrows (Quinn, 1979).

Small vertebrates can also survive fires by retreating to unburned refugia within and around the burn (Quinn, 1986). For example, some lizards survive fires by escaping within rock outcrops (Kahn, 1960) and some bird species have been observed escaping fires by retreating to unburned islands and other safe areas during fires (McClure, 1981). In general, although there is a potential for significant local mortality for some species of small animals, a number of species are capable of retreating from oncoming flames, even if they remain within the immediate burn area.

Much less is known about the direct effects of fire on larger vertebrates. Where studies have been conducted, however, mortality has generally been found to be quite low (Barro and Conard, 1991). In general, larger animals such as mule deer (Odocoileus hemionus), bobcats (Felis rufus), coyotes (*Canis latrans*), and gray foxes (*Urocyon cinereoargenteus*) are capable of escaping fires by fleeing (Peek, 1986; Patton, 1992). For example, in an extensive study of Columbian black-tailed deer (*Odocoileus hemionus columbianus*) in northern California, deer were observed moving ahead of a fire and were seldom injured (Taber and Dasmann, 1957). In addition, carcasses and other evidence of large animal mortality immediately following fires are relatively rare.

Overall, the direct effects of a fire are not considered substantial for most larger animals at the regional level. In addition, although fire impacts can be fairly dramatic for smaller species in localized areas and sometimes result in local extinctions, even small species can escape fires by burrowing and seeking refuge in safe areas. For those species which do suffer fire-induced mortality, the population-level effects over the long-term are not generally considered significant. These species tend to have high reproductive capacities and can readily recolonize recovering habitat from surrounding unburned sites.

Indirect Effects on Wildlife Following a Fire — Postfire Succession

In addition to the potential direct effects of fires on wildlife, fires also dramatically modify the available habitat within burned areas (Peek, 1986; Patton, 1992). In particular, the habitat composition, structure, and resource availability for wildlife may be drastically altered for a wide variety of species and these effects may persist for several years following the fire. However, just as burned vegetation proceeds through a predictable postfire succession sequence, so too do wildlife communities. As the habitat changes and wildlife species recolonize burned areas, the original community eventually begins to reappear and function much as it did prior to the burn.

Much of the empirical work on postfire wildlife recolonization and succession has come from studies of small mammals. A number of important studies have examined this issue in some detail and have led to a fairly complete understanding of the general pattern of postfire small mammal succession in southern California chaparral (e.g., Wirtz, 1982; Wirtz et al., 1988; Quinn, 1990). In general, in the first few months to few years following a fire, small mammal communities change in predictable ways, which primarily reflect the fire survival abilities and habitat preferences of the small mammal species that occur in the area.
Based on various empirical studies of small mammal postfire succession, it is possible to construct a very generalized ten-year postfire sequence which illustrates these points. In the first one to three years following a southern California chaparral fire, species capable of surviving the fire in the burned area and species more adapted to the relatively open habitat conditions found after the burn may predominate. Examples of such species include kangaroo rats (*Dipodomys spp.*), which burrow during fires and prefer more open habitats, and other species, such as deer mice (*Peromyscus maniculatus*) and California voles (*Microtus californicus*), which benefit by more open chaparral. Over the next two to five years, as shrub species recover more fully, habitat generalist species may dominate. For example, California mice (*Peromyscus californicus*) and pocket mice (*Perognathus spp.*), which tend to occur in both open areas and within more densely vegetated cover, may increase in frequency. Finally, after five to ten years, as dense shrub cover returns to the landscape, chaparral-requiring species such as brush mice (*Peromyscus boylii*) and woodrats (*Neotoma spp.*) become most prevalent. At the same time, those species which previously took advantage of the more open areas (e.g. the voles and kangaroo rats) may become rare or absent from the postfire community.

Similar patterns of postfire bird succession have also been observed (Wirtzl 1982; Peek, 1986), with different species dominating at different times over the sequence of habitat changes. For bird species, increased dispersal and movement ability may help explain observed patterns of more rapid postfire succession relative to small mammals.

For large mammal species, postfire use of burned areas also reflects habitat conditions and resource availability, in addition to species-specific adaptations and habitat preferences. In general, most large mammals return fairly quickly to burned areas (e.g. within months) (McClure, 1981), and often take advantage of the modified site conditions resulting from the fire. For example, rapid growth of herbaceous plant species following fires provides abundant and high quality forage for herbivores (Komarek, 1985;; Peek, 1986). In burned areas, this flush of resources can attract and facilitate population increases for herbivores such as deer, which are known to rapidly recolonize and occupy burned areas in large numbers (Taber and Dasmann, 1957; Bleich and Holl, 1982; Tiller et al., 1986). In addition, the abundance of prey following fires facilitates recolonization and occupation by predators, such as coyotes, which have been observed returning to burned areas within weeks after a fire (Wirtz, 1977; McClure, 1981). In general, because of higher resource levels and modified habitat characteristics favorable to a wide variety of species, large mammals may actually be more abundant in the first three to eight years following a fire than before it.

Overall, following initial dramatic habitat changes resulting from a fire, a predictable succession of wildlife recolonization and occupation occurs which reflects patterns of vegetation succession, wildlife species habitat preferences, and species-specific survival probabilities during fires. Although wildlife abundance and species composition may vary through this succession, diversity and richness is little changed over the postfire period.

Fire has been and continues be a natural process in fire-prone natural areas of southern California. Not surprisingly, the species within these communities have evolved a variety of individual mechanisms to respond to fires and to even take advantage of the ecological opportunities available following fire events. Although the indirect effects of fire on wildlife can be dramatic, the overall consequences should be viewed within the context of this natural process and not as a negative impact.

Variables Complicating Fire Effects on Wildlife

The descriptions above provide fairly broad and simplified overviews of the effects of fire on wildlife communities. The ultimate results of a burn, however, will be influenced by a variety of additional complicating variables. Two of these variables, the size and spatial configuration of the burn and the intensity of the fire, can have dramatic effects on how wildlife communities respond to and recover from a fire.

Fire size and spatial configuration can substantially alter postfire wildlife recovery patterns (Quinn, 1979; Peek, 1986). Although some individual animals are able to survive within a burn area immediately after a fire, most must recolonize the site from the periphery of the burn or from unburned refugia in the burned area. In addition, wildlife species that are capable of surviving the direct effects of the fire often depend on the cover and resources available at unburned edges, both within and around the burn. These dependencies have been observed for a variety of species, including rabbits and other small mammals, various birds, and particularly for larger mammals such as deer, coyotes, and other predators (McClure, 1981; Quinn, 1986; Quinn, 1990).

It follows from these observations that a larger, more contiguous burn may result in fewer recolonization sources and less cover and resources available for wildlife. This will alter the recovery patterns for local species by affecting the availability of dispersal opportunities and limiting critical resources needed to maintain populations within recently burned sites. In addition, a larger, more contiguous fire would be expected to provide fewer escape opportunities for wildlife, thus increasing the amount of direct mortality resulting from the burn. Overall, one might expect to find a greater probability for local extinctions in larger burns and a more prolonged succession (i.e., a slower recovery) for some wildlife species (Quinn, 1986).

In addition, a very intense, fast moving fire would be expected to result in increased direct mortality within a burn area (Lawrence, 1966; Peek, 1986; Wirtz et al., 1988). In this situation, fleeing is more difficult, burrowing is less effective, and unburned refugia may be less likely to occur. This may be particularly relevant to Santa Ana wind-driven fires which occur in very dry, old chaparral — fires similar to those that occurred throughout southern California in the fall of 1993.

Very few studies have directly addressed the complicating factors of fire size, configuration, and intensity on wildlife populations (Quinn, 1979; 1986, Wirtz et al., 1988). In fact, most wildlife studies have focused on prescribed burns which not only provide very controlled circumstances, but also tend to be smaller and leave substantial amounts of unburned edge. In these cases, mortality has been found to be relatively low and recovery rates fairly rapid. It is likely, though, that this is not always the general rule. The critical role of unburned refugia and the interacting influences of fire size, shape, and intensity may significantly alter the abilities of wildlife communities to respond to and recover from fire, particularly in large, intense wildfires during Santa Ana conditions.

Overall, while many plant species seem to be fairly well-adapted to a variety of fire intensities and sizes (high fire frequencies may be a significant exception to this rule) these variables may be critical for postfire wildlife successional patterns and recovery rates. From studies of both the direct and indirect effects of fire on wildlife, the mechanisms of wildlife survival and recovery suggest that burn size and shape, and fire intensity will strongly affect postfire recovery patterns. Specifically, larger, more complete, and more intense fires may result in slower recovery and higher local extinction probabilities for a number of wildlife species. These effects may be especially acute in urban parks such as SMMNRA, where habitat is often reduced and fragmented by adjacent development (see Habitat Connectivity and Fire Effects on Wildlife section, page 5-66). In habitat fragments surrounded by an inhospitable urban matrix, burns that cover the whole fragment may cause significant mortality and even local extirpation of particular species, thereby causing long-term community changes.

Species Specific analysis of Fire Effects

Mule Deer (Odecoileus hemonus)

Direct Fire Effects: Mule deer are generally able to outrun even fast moving chaparral fires with a few exceptions noted when they become trapped or encircled by fire.

Indirect Fire Effects: Habitat modification by fire can be beneficial to mule deer. Major changes in plant species diversity in post-fire chaparral, as well the improvement in the nutritional quality of succulent re-sprouts and the post-fire herbaceous flora has been reported to be highly attractive to mule deer by many researchers. Herd size and productivity is limited by the condition of the vegetation utilized by the deer for browse. Mule deer populations in the Santa Monica Mountains could perhaps benefit from by prescribed burn/fuels management programs in some of the old growth chaparral areas of the Santa Monica Mountains. However deer utilize many different habitat types within the Mountains, including chaparral, and the particular quality of these different habitats for deer is unknown.

Mountain Lion (Felis concolor)

Direct Fire Effects: Although no documentation exists, it is probable that most mountain lions are able to escape even fast moving chaparral fires due to mobility and a high degree of intelligence.

Indirect Fire Effects: Modification of wildlife habitat by fire through enhancement of species diversity and nutritional qualities in the vegetation communities has been shown to increase wildlife populations. Mule deer are a major prey item of the mountain lion, and habitat modifications that increased deer populations could be beneficial to mountain lion populations in the Santa Monica Mountains. However the isolated and fragmented nature of the Mountains dictate that the lion population is necessarily limited, and the current status of deer populations is unknown, so deer may not be limiting factor for mountain lions in the Santa Monica Mountains.

Bobcat (Lynx rufus)

Direct Fire Effects: As in the case of mountain lions, bobcats are generally able to escape even fast moving chaparral fires, due to extensive mobility and a high degree of intelligence.

Indirect Fire Effects: Bobcats may be adversely affected by decimation of small mammal populations in the immediate post-fire environment, which may cause the bobcat to relocate its hunting territory. Increases in small mammal populations in subsequent years following the burn due to improved forage and seed production will be beneficial to bobcats. Bobcats are also opportunistic foragers that can probably switch between a different member of the small mammal community for prey, if certain species are more common at different stages post-fire. However appear to prefer rabbits as prey, and so as fire affects rabbit populations, it may also influence bobcats.

Grey Fox (Urocyon cinereorgenteus)

Direct Fire Effects: Due to a high degree of mobility and intelligence, direct mortality of foxes during fires is insignificant in relation to total populations.

Indirect Fire Effects: Initial post-fire effects in terms of reduction, or relocation, of small mammal populations within the burn area can be detrimental to foxes. Subsequent post-fire alteration of vegetation communities in terms of species composition and improved seed production results in increased populations of small mammals which is beneficial to foxes. Foxes appear to utilize dense chaparral communities in many parts of the mountains, so they may be particularly affected by large fires that consume extensive amounts of dense shrubland.

Coyotes (Canis latrans)

Direct Fire Effects: Due to a high degree of mobility and intelligence, direct mortality of coyotes during fires is insignificant in relation to total populations.

Indirect Fire Effects: Initial post-fire declines in small mammal populations which are major prey items in coyote diets will prove detrimental to coyotes, causing them to seek other hunting areas. Subsequent changes in species composition and increased seed production in post-fire flora will result in increases in small mammal populations which could benefit coyotes. Coyotes also prey on deer, so they may benefit from activities which increase deer populations.

Long-tailed Weasel (Mustela frenata)

Direct Fire Effects: Direct mortality of weasels during wildfires is probably rare due to the weasels' ability to escape the lethal effects of a fire in an underground burrow.

Indirect Fire Effects: Most of the small mammals utilized by weasels as prey items are able to escape the lethal effects of a fire by waiting in an underground burrow for the fire to pass. Subsequent changes in post-fire flora will tend to increase small mammal populations thus benefiting weasels by improving their prey base.

Badgers (Taxidea taxus)

Direct Fire Effects: Direct mortality of badgers during wildfires is probably rare due to the badgers' ability to escape the lethal effects of a fire in an underground burrow.

Indirect Fire Effects: The badgers' primary prey items are burrowing animals, most of which survive wildfires by remaining in their burrows while the fire passes. Removal of surface vegetation will make it easier for badgers to locate small mammal burrows.

Rabbits (Sylvilagnus spp.)

Direct Fire Effects: Due to surface dwelling habits and small size, direct mortality of rabbits is high in the event of fast moving chaparral fires.

Indirect Fire Effects: Immediate post-fire alteration of vegetation will cause displacement of most rabbits to adjacent unburned areas. As post-fire flora re-establishes the site, congruent increases in rabbits returning and re-populating the burn area will occur.

Woodrats (Neotoma lepida, N. Fuscipes)

Direct Fire Effects: Direct mortality of woodrats is very high due to surface dwelling habits and slow mobility. Post-fire observations in the Santa Monica Mountains showed more woodrat mortality than any other species of mammal.

Indirect Fire Effects: Woodrats are adapted to living in stands of old growth chaparral and building their nests out of twigs placed in the basal branches of old chaparral plants. Research indicates that woodrats will not re-populate post-fire stands of chaparral until canopy closure of chaparral plants occurs, 7 – 10 years after the fire.

Grey Squirrel (Sciurus grisens)

Direct Fire Effects: Some mortality of grey squirrels can be expected in very intense chaparral fires that burn off the canopies of oak and riparian woodlands which are their primary habitat. Chaparral fires tend to be patchy and burn incompletely in woodlands, providing some areas of escape. Grey squirrels usually seek to escape in the insulated environment of a tree hollow.

Indirect Fire Effects: Destruction of woodlands from chaparral fires would be highly detrimental to grey squirrels. Tree canopy destruction would make the squirrels more susceptible to birds of prey, and lowered acorn and other tree seed production would be detrimental in the immediate post-fire environment.

Ground Squirrel (Osteospermphilus beecheyi)

Direct Fire Effects: Ground squirrels are capable of successfully escaping mortality during fires by waiting in underground burrows for the fire front to pass. Ground squirrels inhabit grasslands where fire intensity is low.

Indirect Fire Effects: Removal of vegetative cover can make ground squirrels more susceptible to predators in the barren post-fire environment. Subsequent improvement in the nutritional quality of post-fire herbaceous flora and increases in seed production will benefit ground squirrels.

Small Mammals

Other mammals include pocket gopher (Thomomys bottae), pacific kangaroo rat (Dipodomys agilis), deer mouse (Peromyscus maniculatus), western harvest mouse (Reithrodontomys megalotis) California mouse (Peromyscus californicus), brush mouse (P. boylii), pinyon mouse (P. truei), cactus mouse (P. emericus), California vole (Microtus californicus), California pocket mouse (Perognathus californicus), et.al.

Direct Fire Effects: Direct mortality of non-burrowing species of small mammals is very high during chaparral fires. These species, which inhabit dense grassland, such as California voles and harvest mice, suffer severe mortality of populations in grassland fires. Species such as the pocket gopher, pocket mouse, and kangaroo rat, which utilize underground burrows, are able to survive fire in the insulated underground environment.

Indirect Fire Effects: Although rodent populations may be severely reduced immediately following a fire, subsequent increases in species diversity, nutritional quality and seed production in post-fire seral vegetation will produce increases in species diversity and total populations of small mammals. There can be a post-fire succession for small mammal species, in which certain species are more or less favored at different times.

Birds

Direct Fire Effects: Direct mortality of birds during chaparral fires is very low due to their ability to escape the fire front by flying away.

Indirect Fire Effects: Wars (1981) found that bird populations and species diversity increase in post-fire chaparral due to increases in seed production and insect populations. Habitat structure alteration may cause the loss of important nesting sites due to the loss of trees, shrubs, or snags, particularly for ground-nesting birds or chaparral requiring birds.

Raptors

Direct Fire Effects: Direct mortality of birds-of-prey during chaparral fires is rare due to the birds' ability to fly away from exposure to the fire.

Indirect Fire Effects: Alteration of habitat structure and composition can have beneficial and detrimental effects on raptors. The destruction of woodlands and trees during intense chaparral fires causes the loss of important nesting habitat and hunting perches for birds-of-prey. Reduced shrub cover can improve hunting success for these birds. Initial decimation of small mammal populations is not a significant problem due to the ability of the raptors to utilize hunting habitat in unburned areas. Raptors, being opportunistic feeders, will feast on the charred bodies of animals killed by fire. Subsequent increases in prey species populations in the post-fire environment will be beneficial to all raptors.

Reptiles

Direct Fire Effects: Direct mortality of reptiles is probably significant in terms of total populations within a burned area, although a large number are capable of escaping the fire in underground burrows and rock piles. Snakes are known to suffer significant direct mortality from fires.

Indirect Fire Effects: Removal of vegetative cover will cause greater susceptibility of reptiles to predation due to lack of escape and hiding cover. Immediate depletion of insect populations will be detrimental to insect-eating lizards, although subsequent increases in post fire insect populations should prove beneficial to the lizards that re-colonize the area. Snakes that feed on small mammals should benefit from increases in post-fire populations. The relative abundance of lizards in burned interior chaparral in the Mazatzal Mountains in Arizona was found to be 10 times that of unburned chaparral. Species diversity and species richness was also greater (Cunningham et al., 2002).

Amphibians

Direct Fire Effects: Many amphibians inhabit aquatic environments, direct mortality during fires should be low for these species. Many adult amphibians, however, including tree frogs, toads, and many salamanders, utilize terrestrial habitats and so they are likely to suffer direct mortality. Terrestrial salamanders that live in oak woodlands may be particularly affected by fires that consume woodlands, though they may be able to escape underground.

Indirect Fire Effects: Even in moist habitats, extreme wildfires may consume riparian vegetative cover and surface organic matter, changing the micro-climate of the environment to a hot dry regime until the vegetation recovers. A significant indirect impact of fire on aquatic habitats is the siltation due to the loss of the vegetative cover that stabilizes soils. This impact is known to occur in and affect amphibians in the Santa Monica Mountains.

Fish

Direct Fire Effects: There is no documented evidence of direct mortality of fish due to wildfire.

Indirect Fire Effects: Siltation of streams, ponds, estuaries, and reservoirs may cause significant impacts to fish populations due to increased turbidity, slower wager flow and higher levels of organic matter in the water.

Insects

Direct Fire Effects: Direct mortality of insects in wildfires is significant, although a great number do escape by flying away or in protected micro-environments such as beneath the soil surface or in the trunks of trees.

Indirect Fire Effects: Force (1982) indicates that species compositions and populations of insects in post-fire chaparral decline significantly from pre-fire conditions. In subsequent years nectar feeding insects dramatically increase due to the profusion of post-fire flowers, and after four years species diversity and total populations reach pre-fire levels.

IV Natural Resources

A3 Biological Resources – Habitat Connectivity and Fire Effects on Wildlife

Many parts of the SMMNRA exist as islands of natural habitat within an urban sea. As a result, among the greatest threats to ecological viability across the region are habitat fragmentation and loss of connectivity caused by increased development and urban encroachment. The effects of fragmentation on wildlife are many and varied and can profoundly affect the ability of remaining wildlands to support wildlife populations (Wilcox 1980, Simberloff and Abele 1982, Shaffer 1981). Fire can exacerbate the effects of habitat fragmentation on wildlife populations in several ways.

Local extinctions are one possible consequence of habitat fragmentation. Extinctions may occur because small, isolated habitat fragments support fewer species than larger more continuous areas (Willis, 1974; Diamond, 1975; Diamond, and May, 1981; Diamond, 1984). The risk of extinction is affected by several mechanisms, such as demographic stochasticity, inbreeding depression, environmental stochasticity, and catastrophes. These mechanisms all relate to the fact that small areas can only support smaller populations, and smaller populations do not persist as long as large populations. For example, biased sex ratios, inbreeding effects (decreased genetic diversity), and catastrophic events can all affect smaller populations and potentially decrease the population's life span in comparison to larger populations. These effects are a greater problem for species that need large ranges (such as mountain lions), or are specific to particular habitats (such as Astragalus brauntonii) (Terborgh, 1974; Wilcox and Murphy, 1985). If wildlands in the Santa Monica Mountains are isolated due to fragmentation, local extinctions are expected. Empirical results from studies of chaparral fragments in San Diego County support this contention (Soulé et al., 1988; Bolger et al., 1991; Soulé et al., 1992).

Fragmented ecosystems experience a new set of impacts from large fires. Fire can act as an extinction mechanism, leading to the local disappearance of certain species from a burned area (Sauvajot, 1995). In an unfragmented system, the long-term population impacts of such extinction events may be inconsequential because of the availability of nearby unburned habitat to serve as a recolonization source. However, if fire-induced extinctions occur in fragmented habitats, local populations may be eliminated entirely if the burn encompasses the entire habitat fragment. In addition, because local population sizes are already relatively small in habitat fragments, fire-associated mortality may actually push population levels below viability thresholds for some species. These reduced populations will be further subjected to various extinction mechanisms, increasing the chances of their removal from the habitat fragment (Gilpin and Soulé, 1986). If the affected fragment is not close enough to recolonization sources, local extinctions can be permanent.

Another important consequence of habitat fragmentation is the loss of connectivity within formerly continuous habitats (Noss, 1987, 1991; Saunders and Hobbs, 1991). Habitat fragmentation within a region can reduce connectivity by isolating habitats from one another. For many species, this removes options for movement between remaining habitat patches. If fire-induced mortality results in local extinctions, the recolonization potential for the area depends on its proximity to other occupied habitats. For example, when a fire burns through an area, postfire recovery for many species depends on their ability to return to the burned landscape from surrounding unburned areas. In a fragmented system, individual patches may be too far apart to allow species movements to occur between patches. If this is the case, a local extinction caused by a fire can be permanent, with little or no chance for the species to return to the patch from which it was removed (Sauvajot, 1995).

In addition, many species rely on their ability to flee oncoming flames to escape fire. This strategy depends on having escape routes within habitat areas which can be used by fleeing wildlife to retreat to safe areas. Loss of connectivity can remove these options, constraining both the ability of wildlife to find escape routes and the availability of safe, unburned refugia. As a result, fire-induced mortality may increase and postfire recovery opportunities may be lost. This will likely affect the long-term persistence of wildlife species in remaining fire-prone natural areas. Thus, the combined effects of fire and fragmentation will work together to increase the chances for species declines in fragmented areas (Sauvajot, 1995).

In human-dominated, fragmented landscapes, frequent fires near fragment edges may facilitate the invasion of edge-associated impacts into natural areas. In particular, the openings and disturbed areas created after fires can accelerate invasions by disturbance-associated exotic plants, increase the entry of development-associated species into natural areas, and facilitate other types of human-caused habitat alteration due to the proliferation of social trails and off-road vehicle access routes (Sauvajot et al., 1998). These impacts can be exacerbated by increased fire frequencies associated with nearby human development (Sauvajot, 1995).

This combination of frequent human-caused fires and disturbance-facilitated impact invasions along the urban-wildland interface may significantly alter the distribution and abundance of native wildlife in fragmented systems. In addition, large, intense fires which are potentially more damaging to native biota may also be more effective at facilitating intrusive edge effects.

In summary, several factors suggest that wildlife persistence and recovery may be substantially altered in fragmented areas following fire (Sauvajot, 1995). First, the combined extinction effects of fire and fragmentation may result in the local disappearance of some species in fragmented areas that have burned. In addition, the loss of habitat connectivity due to fragmentation and development encroachment may limit the ability of some species to respond to and recover from fires. This is because of the decrease in escape routes and increase in barriers and because a loss in connectivity may reduce chances of recolonization after fire. Finally, frequent human-caused fires in fragmented areas may increase edge effects in natural systems, impacting native biota. Each of these effects is exacerbated with the occurrence of large, intense fires.

IV Natural Resources

A4 Biological Resources – Non-native/Invasive Species and Fire Effects

The introduction of herbaceous non-native plants, particularly annual grasses, into shrublands and native grasslands has fundamentally altered the fire-ecology of southern California. These non-native species act in conjunction with the increasing number of fire ignitions associated with human activities, to play a significant role in the loss of native vegetation.

Role of Short Fire Return Intervals on the Establishment of Non-Native Plant Species

Fire return intervals in the Santa Monica Mountains are such that in many areas they threaten the persistence of the dominant shrublands (NPS, 1999). In some areas the average fire return time is as little as ten years and sequences of fires with intervals as short as two years have occurred. The problem is particularly acute in the extensive areas of mixed chaparral dominated by non-sprouting big-pod ceanothus (*Ceanothus megacarpus*), where vegetation can be dramatically and irreversibly altered by a single fire that occurs before plants have matured and seed banks have been replenished. Resprouting species show greater resilience under short fire return intervals, but nevertheless may be severely impacted by sustained high-frequency fire regimes (Lloret and Zedler, 1991; Keeley, 1992a & b; DeSimone, 1995). In species such as the chaparral dominant chamise (*Adenostoma fasciculatum*), mortality of lignotubers can be very high if fire returns prematurely (Kay et al., 1958; Zedler et al., 1983; Haidinger and Keeley, 1993).

Herbs comprise more than three-fourths of the total post-fire flora, but under historic fire return intervals are rapidly displaced as native chaparral shrub species regenerate and the canopy closes. When regeneration of native shrubs is hindered or native shrubs are eliminated entirely by repeated fires, the opportunity exists for non-native annual grasses to persist at the site. These species in turn can induce fire and nutrient feedback cycles that can lead to vegetation-type conversion.

The Role of Non-Native Herbaceous Flora in Vegetation Type Conversion

Once introduced into an area, annual grasses can increase fire frequency by changing the amount, distribution, and time of available fuels for fire (Giessow, 1997). These grasses complete their life cycle early in summer season, but do not easily decompose (D'Antonio and Vitousek, 1992; O'Leary, 1995). This results in a large amount of fine standing dead fuel that supports very rapid rates of fire spread under a broader range of weather conditions than chaparral (Barro and Conard, 1987). Dry grasses have the lowest heat requirements for ignition and therefore have the longest fire season and highest fire frequency of any southern California vegetation type (Radtke, 1983). Most importantly, the capacity of exotic herbaceous fuels to burn is little influenced by previous fire history. Herbaceous fuel build-up is sufficient to support fire return intervals of one or two years, a cycle that will eliminate shrub communities (Zedler et al., 1983; Nadkarni and Odion, 1986; Minnich and Dezzani, 1998).

Although grass fires are less intense than shrub fires, they nevertheless consume native seedlings (Barro and Conard, 1987). If fire recurs at sufficiently short intervals or at inappropriate times, it can also kill resprouting shrubs (Murphy, 1968; Radtke, 1981; Zedler et al., 1983). At the same time, low-intensity grass fires can result in reduced seed mortality of opportunistic non-native annuals (Moreno and Oechel, 1991a; Stephen Davis, personal communication). A positive-feedback cycle is thus initiated, where fire opens the shrub canopy allowing establishment of exotic herbs, the presence of exotic herbs increases fire frequency and frequent fires further increase the abundance of exotic herbs (Giessow, 1997). High fire frequency is perpetuated and ultimately there is type conversion of shrublands to exotic grasslands (Keeler-Wolf, 1995).

In addition to changing fire frequency, non-native grasses and forbs also alter nitrogen and organic matter cycles (Zink et al., 1995), and may strongly compete for water and nutrients (Schultz et al., 1955; D'Antonio and Vitousek, 1992; O'Leary, 1995b; Eliason and Allen, 1997). Native annuals compete poorly and are quickly eliminated with the introduction of exotics (Keeley et al., 1981). Establishment of native shrub seedlings is also inhibited and even in the absence of repeated fires coastal sage and chaparral shrubs show only a limited ability to reinvade sites dominated by exotic annual grasses and forbs (Zedler and Zammit, 1989, Callaway and Davis, 1993; Haidinger and Keeley, 1993; Minnich and Dezzani, 1998).

Fire Management and Non-Native Species

Low intensity, out of season prescribed fires eliminate non-sprouters and reduce resprouting from lignotubers without triggering germination of replacement seedlings, creating gaps in the recovering vegetation canopy. At the same time low intensity burning can fail to produce sufficient heat to destroy seeds of opportunistic annuals (Moreno and Oechel, 1991a; Stephen Davis, personal communication). Prescribed burning, unless performed under high intensity prescriptions, can create conditions favorable to the introduction of exotic weeds, which compete strongly with native herbaceous flora and because of their increased flammability can increase the potential for initiation of a positive feedback cycle of increasing fire frequency and increasing numbers of weeds. The problem can be exacerbated when control lines are anchored at fuel breaks, trails or other access points that support high numbers of weeds (Giessow, 1997; Fabritius and Davis, 2000). While utilizing existing vegetation breaks is greatly preferable to cutting new lines through vegetation, the general failure to clear these areas of exotics can result in enhanced post-burn weed ingression. Similarly fuels breaks, as well as trails and roads, serve as sources for introduction of non-native species after wildfires into a native vegetation matrix that would otherwise be more greatly protected by distance from exotic sources.

IV Natural Resources

A5 Biological Resources – Rare, Threatened and Endangered Species

Twenty-three plant and animal species with potential to occur within the SMMNRA are federally listed as sensitive (S), threatened (T), or endangered (E). Three additional state-listed species occur within the Santa Monica Mountains. Another 46 animal and 12 plant species are federal or state species of concern (SC) and one additional plant species has been proposed for listing as federally endangered (a listing package has been prepared). In addition, a number of other plant and animal species are considered rare (R) or are species of concern to the recreation area. A comprehensive list of these species is provided in the following tables (Tables 3-8 and 3-9).

IV Natural Resources

A5a Biological Resources – Rare, Threatened and Endangered Species: Sensitive Species – Plants

Table 3-8 Sensitive Plant Species of the Santa Monica Mountains

Species Name	Federal	State
Cordylanthus maritimus ssp. maritimus Salt marsh bird's-beak	E	E
Pentachaeta lyonii Lyon's pentachaeta	E	E
Astragalus brauntonii Braunton's milk-vetch	E	-
Dudleya cymosa ssp. marcescens marcescent dudleya	T	R
Dudleya cymosa ssp. ovatifolia Santa Monica Mtns. dudleya	T	-
Dudleya abramsii ssp. parva Conejo dudleya	T	-
Dudleya verityi Verity's dudleya	T	-
Eriogonum crocatum Conejo buckwheat	SC	R
Hemizonia minthornii Santa Susana tarplant	SC	R
Calochortus plummerae Plummer's mariposa lily	SC	-
Delphinium parryi ssp. blochmaniae Dune larkspur	SC	-
Dudleya blochmaniae ssp. blochmaniae Blochman's dudleya	SC	-
Dudleya multicaulis Many-stemmed dudleya	SC	-
Lasthenia glabrata var. coulteri Coulter's goldfields	SC	-
Chorizanthe parryi var. parryi Parry's Spineflower	SC	-
Nolina cismontana California beargrass	SC	-
Atriplex coulteri Coulter's saltbush	-	S
Nama stenocarpum Mud nama	-	S

Table 3-8 continued

Species Name	Federal	State
Senecio aphanactis Rayless ragwort	-	S
Thelypteris puberula var. sonorensis Sonoran maiden fern	-	S
Camissonia lewisii Lewis's evening-primrose	-	S
Hordeum intercedens Vernal barley	-	S
Abronia maritima Red sand-verbena	-	S
Baccharis plummerae ssp. plummerae Plummer's baccharis	-	S
Boykinia rotundifolia Round-leaved boykinia	-	S
Calandrinia maritima Seaside calandrinia	-	S
Cercocarpus betuloides var. blancheae Island mountain-mahogany	-	S
Chamaebatia australis Southern mountain misery	-	S
Dichondra occidentalis Western dichondra	-	S
Erysimum insulare ssp. suffrutescens Suffretescent wallflower	-	S
Galium cliftonsmithii Santa Barbara bedstraw	-	S
Juncus acutus ssp. leopoldii Southwestern spiny rush	-	S
Lepechinia fragrans Fragrant pitcher sage	-	S
Polygala cornuta var. fishiae Fish's milkwort	-	S
Suaeda esteroa Estuary seablite	-	S
Baccharis malibuensis Malibu baccharis	-	S

Fire Effects on Rare, Threatened and Endangered Plant Species

The plants listed as rare, threatened or endangered either occur in areas where fire effects are minimal in terms of habitat alteration (rocky outcrops, salt marshes) or they have evolved in an environment where fire plays a role in the maintenance and productivity of their habitat. It is not anticipated that the proposed fire management program will have a negative effect on these species and in some areas may enhance habitat for species now reduced in population due to fire exclusion. The following discussion focuses on the federally listed plants that may be affected by NPS fire management actions.

Pentachaeta lyonii (Lyon's pentachaeta)

Pentachaeta lyonii is an annual sunflower that occupies pocket grasslands occurring in openings in chaparral and coastal sage. It is restricted to the central and western portion of the Santa Monica Mountains and the western Simi Hills. Of the approximately thirty-two known populations, only one occurs on a NPS site, at Rocky Oaks. However, *Pentachaeta* once occurred at Arroyo Sequit and sites such as Paramount Ranch have high potential (appropriate habitat and nearby existing populations) to support populations of the plant.

Wildfires generally occur after *Pentachaeta* has completed its growth cycle and have no direct impact on the plant. In several instances populations have been observed to expand after fires. This response is likely due to the removal of competitors and opening of suitable habitat rather than a direct fire stimulus (Keeley, 1995; USFWS 1999). However, the ingression of non-native annual grasses and herbs associated with increasing fire frequencies in the Santa Monica Mountains indirectly impact *Pentachaeta*. Competition from these non-native plants is believed to pose a significant threat (Keeley and Keeley, 1992; Fotheringham and Keeley, 1998; USFWS, 1999). The severe disruption of soils associated with grading of control lines for fire suppression may adversely affect *Pentachaeta*, although hand fire lines could potentially be beneficial.

Astragalus brauntonii (Braunton's milk-vetch)

Astragalus brauntonii is a short-lived perennial largely restricted to the Santa Monica Mountains and the Simi Hills. Small populations also occur in the San Gabriel Mountains north of Monrovia and in the Santa Ana Mountains. *Astragalus* is associated with carbonate soils in chaparral and the rarity of carbonate outcrops within the species' range may in large part account for the plant's rarity. Populations of *Astragalus* occur on NPS property in Palo Comado Canyon and Zuma Canyon. The latter population consists of several hundred individuals. There is potential for *Astragalus* to occur at additional areas within these canyons and at other NPS sites.

Recruitment of seedlings is stimulated by fire events, which scarify the hard seed coats of dormant seeds and provide the open, unshaded conditions necessary for growth. Like most chaparral fire following herbs, seeds can persist in the soil over relatively long fire-free intervals. However, unlike typical "fire-type" herb species, *Astragalus* is not necessarily restricted to recent burn sites (Fotheringham and Keeley, 1998). Germination of dormant seeds can be induced by mechanical scarification and a portion of the seeds germinates readily with no pre-treatment. Populations persist for several years after fire, with new individuals recruited over successive years, until recovering shrub species crowd out the *Astragalus*. The ability of seeds to germinate without fire stimulus allows plant stands to be maintained in disturbed or naturally open areas. The disruption of soil that occurs in grading fire control lines may negatively impact Astragalus, although grading activities for development are known to have stimulated seed germination. Competition from the high numbers of alien weeds and concentrated herbivory observed in areas disturbed by control line construction or opened by prescribed burning may negatively impact growth and seed set of *Astragalus*.

Dudleya species

D. cymosa ssp. ovatifolia (Santa Monica Mountains dudleya), *D. cymosa ssp. marcescens* (marcescent dudleya), *D. abramsii ssp. parva* (Conejo live-forever), *D. verityi* (Verity's live-forever), *D. blochmaniae ssp. blochmaniae* (Blochman's dudleya).

Dudleya (live-forever) species are succulent, rosette forming plants that inhabit rock outcrops and rocky soils. With the exception of *D. cymosa ssp. ovatifolia*, which also occurs at two locations in the Santa Ana Mountains, all of the federally listed threatened species are endemic to the Santa Monica Mountains and the western end of the Simi Hills. All species show strong substrate and microhabitat preferences. *Dudleya cymosa ssp. marcescens* occurs on the lower reaches of sheer volcanic rock surfaces and canyon walls adjacent to perennial streams in coast live oak woodland. *Dudleya cymosa ssp. ovatifolia* occurs on rock outcroppings along shaded deep canyon bottoms and while its "Agoura" form occurs along exposed north facing slopes. *Dudleya verityi* grows on north facing rock outcrops in coastal sage scrub. *Dudleya abramsii ssp. parva* and *D. blochmaniae ssp. blochmaniae* grow in shallow rocky soils in grassland and sage scrub (USFWS, 1999). Because these habitats occur in a patchy manner within shrubland community types, *Dudleya* populations tend to have localized distributions.

Dudleya cymosa ssp. ovatifolia occurs on NPS parkland in Zuma Canyon and has been reported (but not confirmed) in Trancas Canyon. *Dudleya cymosa ssp. marcescens* occurs at the Circle X Ranch site. NPS parklands support ample habitat for both *Dudleya cymosa* subspecies and it is likely that more locations will be found as surveys continue. *D. blochmaniae ssp. blochmaniae* occurs in lower Zuma Canyon. *Dudleya verityi* and *Dudleya abramsii ssp. parva* have restricted distributions in the west end of the Santa Monica Mountains and Mountcleff Ridge respectively and are not likely to be found on existing NPS parkland.

Dudleya is easily killed by fire. In addition, the *Dudleya* species that occur on rock faces are often associated with Spike-moss (*Selaginella bigelovii*), mosses, and cushion lichens, which serve as nursery-beds for seed capture and germination (Riefner, 1992). These nursery species are also fire sensitive and any fire that reduces or eliminates these species would remove the necessary substrate they provide for unknown but potentially long periods of time (USFWS, 1999). Because of the restricted and isolated occurrences of populations it is possible that individual populations could be lost in fire events and it is not known how easily natural recolonization would occur. Because plants grow on rock outcroppings of generally low vegetation cover and in areas of generally higher water availability there is a degree of protection from the intense fire that consumes open chaparral. The best evidence of this protection is the persistence of the existing populations through recent fires. It is unlikely that *Dudleya* would be impacted by fire suppression activities, with the exception of *D. blochmaniae ssp. blochmaniae* which grows on open ground is therefore susceptible to loss during control line grading.

<u>Other Sensitive Plant Species</u>

The other sensitive species listed above are not expected to be directly adversely affected by normal fire conditions. The chaparral, coastal sage scrub, and coastal bluff species are generally adapted to or can tolerate recurring fire, while species growing in riparian areas (*e.g. Thelypteris puberula var. sonorensis*) or rocky bluffs (*e.g. Hemizonia minthornii*) are somewhat protected from fire. Fires, may however affect local individual populations. The largest threat to these species is increasing fire frequencies, which in some areas are beyond the capacity for individual species and/or vegetation to recover, and the subsequent increase in highly competitive non-native grasses and herbs. Fire management activities, such as burning out of season or grading of control lines may also adversely impact these species.

IV Natural Resources

A5b Biological Resources – Rare, Threatened and Endangered Species: Sensitive Species – Wildlife

Table 3-9 Sensitive Wildlife Species of the Santa Monica Mountains

Mammals	Federal	State
Euderma maculatum Spotted Bat	SC	S
Eumops perotis californicus Greater Western Mastiff Bat	SC	S
Macrotus californicus California Leaf-nosed Bat	SC	S
Myotis lucifugus occultus Occult Little Brown Bat	SC	S
Plecotus townsendii townsendii Pacific Western Big-eared Bat	SC	S
Sorex ornatus salicornicus Salt Marsh Ornate Shrew	SC	S
Taxidea taxus American Badger	--	SS

Table 3-9 continued

Birds	Federal	State
Pelecanus occidentalis californicus Brown Pelican	FE	SE
Gymnogyps californianus California Condor	FE	SE
Haliaeetus leucocephalus Bald Eagle	FT	SE
Buteo swainsoni Swainson's Hawk	–	ST
Falco peregrinus anatum Peregrine Falcon	FE	SE
Rallus longirostris levipes Light-footed Clapper Rail	FE	SE
Charadrius alexandrinus nivosus Western Snowy Plover	FT	S
Sterna antillarum browni California Least Tern	FE	SE
Brachyramphus marmoratus Marbled Murrelet	FT	SE
Empidonax traillii extimus Southwestern Willow Flycatcher	FE	SE
Riparia riparia Bank Swallow	–	ST
Polioptila californica California Gnatcatcher	FT	S
Vireo belli pusillus Least Bell's Vireo	FE	SE
Passerculus sandwichensis beldingi Belding's Savannah Sparrow	SC	SE
Ixobrychus exilis hesperis Western Least Bittern	SC	S
Pelecanus erythrohynchos American White Pelican	–	S
Histrionicus histrionicus Harlequin Duck	SC	S
Aquila chrysaetos Golden Eagle	–	S
Accipiter cooperii Cooper's Hawk	–	S
Circus cyaneus Northern Harrier	–	S

Table 3-9 continued

Pandion haliaetus Osprey	–	S
Falco columbarius Merlin	–	S
Falco mexicanus Prairie Falcon	–	S
Oreortyx pictus Mountain Quail	SC	–
Numemius americanus Long-billed Curlew	S	
Sterna elegans Elegant Tern	SC	S
Asio otus Long-eared Owl	–	S
Athene cunicularia Burrowing Owl	–	S
Eremophila alpestris actia California Horned Lark	SC	S
Campylorhynchus brunneicapillus couesi San Diego (Coastal) Cactus Wren	SC	S
Lanius ludovicianus Loggerhead Shrike	SC	S
Agelaius tricolor Tri-colored Blackbird	SC	S
Aimophial ruficeps canescens Southern California Rufous-crowned Sparrow	SC	S
Dendroica petechia Yellow Warbler	–	S
Reptiles	**Federal**	**State**
Clemmys marmorata pallida Southwestern Pond Turtle	SC	S
Phrynosoma coronatum blainvillei San Diego Horned Lizard	SC	S
Phrynosoma coronatum frontale California Horned Lizard	–	S
Cnemidophorus tigris multiscutatus Coastal Western Whiptail	SC	–
Anniella pulchra pulchra Silvery Legless Lizard	–	S

Table 3-9 continued

Reptiles	Federal	State
Diadophis punctatus modestus San Bernardino Ringneck Snake	SC	–
Lampropeltus zonata pulchra San Diego Mountain King Snake	SC	S
Lichanura trivirgata roseofusca Coastal Rosy Boa	SC	–
Salvadora hexalepis virgultea Coast Patch-nosed Snake	SC	S
Thamnophis hammondii Two-striped Garter Snake	SC	–

Amphibians	Federal	State
Rana aurora draytoni California Red-legged Frog	FT	S
Taricha torosa torosa Coast Range Newt	–	S

Fishes	Federal	State
Eucyclogobius newberryi Tidewater Goby	FE	SCT
Oncorhynchus mykiss S. California Steelhead Trout	FE	–

Invertebrates	Federal	State
Euphydryas editha quino Wright's Checkerspot Butterfly	FE	–
Speyeria callippe callippe Callippe Silverspot Butterfly	FPE	–
Lycaena arota nubila Clouded Tailed Copper Butterfly	SC	–
Panoquina errans Salt Marsh Skipper	SC	–
Satyrium auretorum fumosum Santa Monica Mountains Hairstreak	SC	–
Brennania belkini Belkins Dune Tabanid Fly	SC	–
Neduba longipennis Santa Monica Shieldback Katydid	SC	–
Proceratium californicum Valley Oak Ant	SC	–

Fire Effects On Rare, Threatened and Endangered Wildlife Species

The effects of fire on threatened, endangered or sensitive species are dependent on the uniformity, severity, size, duration and season of the fire, as well as the animal's mobility to escape the fire, and their existing population demography. In all groups of animals, small and restricted populations, or those with specialized reproductive habits, are most susceptible to fire as direct mortality can cause local extinctions. Most species are not endemic to the park.

Mammals

Seventeen species of mammals within the Santa Monica Mountains are regarded as species of special concern by federal, state, and park agencies. Bats comprise eleven of the seventeen species, and terrestrial mammals make up the rest. Little is known about bats in the mountains. Currently, an inventory is being completed to assess bat diversity and destruction of structures (i.e. tree snags, buildings) by fire, which can eliminate roosting habitat for sensitive bat species. Many terrestrial mammals can avoid fire by retreating to areas not affected by fire (i.e. below ground, between rock crevices). In some small mammal species, however, poor ventilation and high temperatures within underground burrows can cause high mortality. Ground nesting species (e.g. woodrats) are more susceptible to fire since nests are usually built of flammable materials. Most small mammal populations are affected by fire during the breeding season with high juvenile mortality, however, high reproductive rates in some mammals can offset offspring loss due to fire. Larger mammals (e.g. mountain lion) are less vulnerable to fire, however, fires moving fast with heavy ground smoke can cause some mortality. Removal of vegetative cover and litter layer by fire can decrease abundance in some species however can expose certain species to food items (e.g. seeds, carcasses) made available by fire.

The following is more specific information on the requirements and potential fire effects for the various sensitive mammal species:

Sorex ornatus salicornicus. **Salt Marsh Ornate Shrew**
Very little is known about this subspecies or about its habitat requirements. We do not have recent knowledge of whether and where it occurs in the Santa Monica Mountains.

Taxidea taxus. **American Badger**
Badgers definitely occur in the Santa Monica Mountains and in surrounding areas such as the Simi Hills, but we know little about the status or distribution of current populations. Badgers live in underground dens, prefer more open, grassy areas, and often hunt fossorial mammals such as ground squirrels or pocket gophers. Badgers may benefit from fires in some cases because of the opening up of chaparral habitat. They are reported to move into burned chaparral areas in the Sierra Nevada (Lawrence, 1966). Because the badger is a rare animal in the mountains, their populations may be more sensitive to the effects of catastrophes such as large fires.

Bats of Concern
Euderma maculatum (Spotted Bat), likes to roost in cliffs and hunt in clearings. It hunts mostly moths. *Eumops perotis californicus* (Greater Western Mastiff Bat), is a rock crevice roosting bat.

Macrotus californicus (California Leaf Nosed Bat), roosts in mine tunnels and caves. *Myotis lucifugus occultus* (Occult Little Brown Bat), hibernates in caves and mines, and may roost in houses and other buildings in summer. It forages over water and other open spaces. *Plecotus (Corynorhinus) townsendii townsendii* Pacific Western Big Eared Bat, roosts in mines and caves, and eats almost strictly moths. It forages over open woodlands and is very sensitive to disturbance.

All of these bats are insect eaters, and none of them use trees as primary roost sites. Fire/smoke could directly affect roost sites, which may change during the year as temperature changes. Most bats are born in the late spring, but there is a lot of variability.

Birds

Over 60 species of birds are considered threatened, endangered or of special concern within the Santa Monica Mountains. Most species on the list do not breed in the park but rather, occur as residents, utilizing the mountains during the non-breeding season. Shorebirds (~16 species) and other waterbirds (~4 species) are least affected by fire as food niches occur in habitats that are not fire-prone (i.e. coastal beaches, lakes). Raptors (~20 species) are also unaffected or respond favorably to burned areas as fire causes immediate post-fire prey mortality for scavengers and exposes vegetative cover for prey resources. The effects of fire on insect- and plant-eating birds (~21 species) are dependent on food availability and vegetative cover. Most mortality is from nestlings and fledglings than from adults. Some birds are attracted to burning areas as fire drives out insects however most birds are forced out of their habitat. Long-term viability of some species is dependent on the tendency to re-nest following fire. It is shown that burned areas have a lower abundance of species 1-2 years following a fire and reproductive success is lower than pre-fire years but recover 2-3 years later as food and vegetative cover increases.

Special consideration should be made to federal and state listed species. California Condors and Bald Eagles are historic to the mountains. There have been no current sightings of these species in the mountains. Brown Pelicans, Light-footed Clapper Rails, California Least Terns, and Western Snowy Plovers, and Belding's Savannah Sparrow are found primarily along coastal shore or marshes are unlikely affected by fire. Populations of Southwestern Willow Flycatchers and Least Bell Vireos can be negatively affected if fire destroys riparian habitat where they occur. There is no record of the California Gnatcatcher within the Santa Monica Mountains however removal of coastal sage scrub habitat via fire or vegetative conversion can negatively affect the population.

The following is more specific information on the requirements and potential fire effects for the various sensitive bird species:

Aquatic Birds
The following birds spend most of their life histories in or around water bodies (e.g. coasts, lakes). They are unlikely to be affected by any fire activity.

- Migrants and Vagrants

  ***Brachyramphus marmoratus*. Marbled Murrelet**
  Federal Status: Threatened
  State Status: Endangered
  Park Status: Occasional Vagrant

- Winter Residents

  ***Pelecanus erythrohynchos*. American White Pelican**
  Federal Status: No Status
  State Status: Species of Concern
  Park Status: Rare (Winter) Resident

  ***Histrionicus histrionicus*. Harlequin Duck**
  Federal Status: Species of Concern
  State Status: Species of Concern
  Park Status: Occasional (Winter) Resident

  ***Numemius americanus*. Long-billed Curlew**
  Federal Status: No Status
  State Status: Species of Concern
  Park Status: Common (Winter) Resident

- Year-round Residents

  ***Pelecanus occidentalis californicus*. Brown Pelican**
  Federal Status: Endangered
  State Status: Endangered
  Park Status: Abundant Resident

  ***Sterna elegans*. Elegant Tern**
  Federal Status: Species of Concern
  State Status: Species of Concern
  Park Status: Common Resident

  ***Ixobrychus exilis hesperis*. Western Least Bittern**
  Federal Status: Species of Concern
  State Status: Species of Concern
  Park Status: Occasional Resident

- Breeders

The following birds are known to breed within the recreation area (specifically Mugu Lagoon). They may be affected by fire if their breeding habitat is disturbed or destroyed.

***Rallus longirostris levipes*. Light-footed Clapper Rail**
Federal Status: Endangered

State Status: Endangered
Park Status: Rare Breeder

***Charadrius alexandrinus nivosus*.** **Western Snowy Plover**
Federal Status: Threatened
State Status: Species of Concern
Park Status: Uncommon Breeder

***Sterna antillarum browni*.** **California Least Tern**
Federal Status: Endangered
State Status: Endangered
Park Status: Uncommon Breeder

Terrestrial Birds

- Locally Extinct/Extirpated

***Gymnogyps californicus*.** **California Condor**
Federal Status: Endangered
State Status: Endangered
Park Status: Historic (Occasional Breeder)

***Haliaeetus leucocephalus*.** **Bald Eagle**
Federal Status: Threatened
State Status: Endangered
Park Status: Occasional (Winter) Resident
Bald Eagles usually migrate in the fall to the coast or large open water bodies for the winter. As an occasional winter resident here in the Santa Monica Mountains, it is unlikely affected by fire.

***Agelaius tricolor*.** **Tri-colored Blackbird**
Federal Status: Species of Concern
State Status: Species of Concern
Park Status: Rare Breeder

- Migrants and Vagrants

***Empidonax traillii extrimus*.** **Southwestern Flycatcher**
Federal Status: Endangered
State Status: Endangered
Park Status: Uncommon Migrant
***Riparia riparia*.** **Bank Swallow**
Federal Status: No Status
State Status: Threatened
Park Status: Occasional Migrant

***Vireo belli pusillus*. Least Bell's Vireo**
Federal Status: Endangered
State Status: Endangered
Park Status: Occasional Migrant

***Polioptila californica*. California Gnatcatcher**
Federal Status: Threatened
State Status: Species of Concern
Park Status: Unknown
Few individuals perish in fire, but populations within burn areas rapidly decline due to loss of habitat. Birds are absorbed into unburned areas on the periphery and unburned pockets are important refugia (Bontrager et al, 1995).

***Buteo swainsoni*. Swainson's Hawk**
Federal Status: No Status
State Status: Threatened
Park Status: Occasional Migrant

- Winter Residents

***Falco columbarius*. Merlin**
Federal Status: No Status
State Status: Species of Concern
Park Status: Uncommon (Winter) Resident
Merlins may be found in a wide variety of habitats during the winter, but being uncommon, they are unlikely to be affected by fire.

***Falco mexicanus*. Prairie Falcon**
Federal Status: No Status
State Status: Species of Concern
Park Status: Rare (Winter) Resident
As a rare winter resident, it is unlikely that Prairie Falcons will be affected by fire.

- Year-round Residents

Birds that are year-round residents can be affected by fire if prey resources are eliminated. The following birds are known breeders. Each is followed up with a description of their foraging grounds.

***Falco peregrinus*. Peregrine Falcon**
Federal Status: Endangered
State Status: Endangered
Park Status: Uncommon Resident
There are historical reports of Peregrine Falcons nesting along the cliff faces in the Santa Monica Mountains however current information suggests that they are no longer breeders within the mountains. As a resident, they may be affected by fire if there is a reduction in prey availability.

***Circus cyaneus*. Northern Harrier**
Federal Status: No Status
State Status: Species of Concern
Park Status: Common Resident
Northern Harriers forage over open grasslands within the mountains. Reduction of vegetative cover for prey may reduce food resources for this species.

***Pandion haliaetus*. Osprey**
Federal Status: No Status
State Status: Species of Concern
Park Status: Uncommon Resident
The foraging preferences of the Osprey make this species unlikely to be affected by fire.

- Breeders

Birds that are breeders in the mountains can be affected by fire if nesting habitat and prey resources are eliminated. The following birds are known breeders. Each is followed up with a description of their breeding and foraging grounds.

***Passerculus sandwichensis beldingi*. Belding's Savannah Sparrow**
Federal Status: Species of Concern
State Status: Endangered
Park Status: Common Breeder
Nesting occurs primarily in pickleweed habitat at the higher elevations of the salt marshes, above the reach of the highest spring tide (Mugu Lagoon).

***Oreortyx pictus*. Mountain Quail**
Federal Status: No Status
State Status: No Status
Park Status: Uncommon Breeder
Mountain Quail occur in chaparral, brushy ravines and mountain slopes. Species such as manzanita, whitethorn buckbrush and chamise from 18 inches to an optimal four to seven feet protects the birds from the elements and predators. Brush should cover approximately 30 percent to 60 percent of mountain quail habitat.

***Eremophila alpestris actia*. California Horned Lark**
Federal Status: No Status
State Status: Species of Concern
Park Status: Uncommon Breeder
When not flying, California Horned Larks move across the ground by walking. They live in grasslands and other sparsely vegetated habitat. Horned larks use grasses, rocks, and other elements of the terrain as cover from predators when feeding. Food typically consists of grass seeds and other plant matter. Insects, spiders, and snails are the main food source during the breeding season (Zeiner, D.C., et al., eds. 1990. California's Wildlife. 3 vols. Sacramento, California: Department of Fish and Game).

***Campylorhynchus brunneicapillus couesi*. San Diego (Coastal) Cactus Wren**

Federal Status: No Status

State Status: Species of Concern

Park Status: Uncommon Breeder

A sedentary resident, the Cactus Wren is associated with patches of cholla or prickly pear cactus in coastal sage scrub vegetation (Rea, Amadeo M. and Kenneth L.; Weaver, 1990. The taxonomy, distribution and status of the coastal California cactus wren. Western Birds 21(3):81-126). Most birds survive the direct effects of fire, but populations decline somewhat due to loss of cactus scrub habitat. Because cactus scrub is somewhat resistant to fire, populations declines within burn areas are not as severe as for birds restricted to woody shrub species. Unburned areas on the periphery do not absorb birds from within the burn area, but unburned patches within the fire perimeter are important refugia (Bontrager et al, 1995).

***Lanius ludovicianus*. Loggerhead Shrike**

Federal Status: Species of Concern

State Status: Species of Concern

Park Status: Rare Breeder

Loggerhead Shrike prey consists of various insects, lizards, mice, and birds. Insects such as bumblebees, dragonflies, grasshoppers, and crickets are preferred. Other prey items include crayfish and snails. Loggerhead Shrikes live in open, thinly wooded land or scrub savanna with clearings. Meadows, pastures, old orchards, and particularly osage orange hedges are often favored by these birds (Terres, J. K. 1982. The Audubon Society Encyclopedia of North American Birds. New York: Knopf).

***Aimophila ruficeps canescens*. Southern California Rufous-crowned Sparrow**

Federal Status: Species of Concern

State Status: Species of Concern

Park Status: Uncommon Breeder

Rufous-Crowned ASarrow occurs in sparse, mixed chaparral and coastal scrub habitats (especially coastal sage) and frequently found in open shrubland, open chaparral, and relatively steep, often rocky hillsides with grass and forb patches; also grassy slopes without shrubs, if rock outcrops are present. It forages on the ground in herbage and in litter beneath shrubs, gleaning from the ground and foliage; also gleans foliage of live oaks. It eats seeds, insects, spiders, grass and forb shoots. Nests are concealed on the ground at the base of shrubs. (Verner, J., and A. S. Boss. 1980. California wildlife and their habitats: Western Sierra Nevada. U.S. Dep. Agric., For. Serv., Berkeley. Gen. Tech. Rep. PSW-37. 439pp).

***Dendroica petechia*. Yellow Warbler**

Federal Status: No Status

State Status: No Status

Park Status: Rare Breeder

In southern California, Yellow Warblers typically nest in habitats with a dense understory vegetation (i.e. California Wild Rose (*Rosa californica*), various shrubby willows (*Salix spp.*) and Mulefat (*Baccharis salicifolia*)).

***Asio otus*. Long-eared Owl**
Federal Status: No Status
State Status: Species of Concern
Park Status: Rare Breeder
Long-eared Owls generally place their nests within woodland and riparian habitat found throughout the mountains as well as forage over open fields and grassland. Elimination of these habitats by fire may reduce the amount of available nesting sites and food resource availability.

***Athene cunicularia*. Burrowing Owl**
Federal Status: No Status
State Status: Species of Concern
Park Status: Rare Breeder
Burrowing Owls make their homes in the ground within the grassland habitats of the mountains. They are believed to be protected from the direct effects of fire in their burrows. Prey availability may be reduced if foraging habitat is eliminated by fire.

***Aquila chrysaetos*. Golden Eagle**
Federal Status: No Status
State Status: Species of Concern
Park Status: Uncommon Breeder
Locally uncommon but known to nest along cliffs within the mountains, Golden Eagles are unlikely to be affected by fire.

***Accipiter cooperii*. Cooper's Hawk**
Federal Status: No Status
State Status: Species of Concern
Park Status: Common Breeder
Considered a common breeder, elimination of riparian corridors by fire may reduce the Cooper's Hawks likelihood of foraging and nesting habitat within the Santa Monica Mountains.

Reptiles, Amphibians and Fish

There are 22 species of reptiles and amphibians within the Santa Monica Mountains regarded as threatened, endangered or of special concern by federal, state, and park agencies. Currently, an inventory is being completed to assess herpetofaunal diversity within the mountains and elimination of habitat by fire can negatively affect sensitive populations. Most species can escape fire by burrowing (e.g. turtles) or moving away from impacted areas. Mortality can occur in some snake species if they are in ecdysis (the process of shedding skin). Riparian zones and other moist areas favored by many amphibians are less likely to burn however increased sedimentation and run off in burned areas following fire has been shown to reduce the amount of available breeding habitat for some amphibian species (Gamradt and Kats, 1997). The conversion of habitat by fire has the biggest effect on species diversity. Some burned areas show a high density of reptile species, especially those species typically found in open areas.

The following is more specific information on the requirements and potential fire effects for the various sensitive reptile, amphibian, and fish species:

- Reptiles

***Clemmys marmorata pallida*. Southwestern Pond Turtle**
Southwestern pond turtle is a semi-aquatic species commonly found in streams, ponds, lakes, and marshes, but also utilizes upland habitats seasonally. Effects due to fire would be the loss of riparian and adjacent upland vegetation, increasing water temperatures due to loss of canopy cover, and siltation of pools in stream channels.

***Phrynosoma coronatum*. San Diego Horned Lizard**
Horned lizard can be found in variety of habitats (coastal sage scrub, oak woodlands, chaparral, and grasslands). The limiting factors for these species are areas with loose sandy soils and an abundance of native ant species. Coast horned lizards like open microhabitats that may be created following fire events.

***Cnemidophorus tigris*. Coastal Western Whiptail**
Coastal Western Whiptail are common in the Santa Monica Mountains and prefer open habitats with shrub for cover nearby. Effects due to fire are unknown.

***Anniella pulchra pulchra*. Silvery Legless Lizard**
This species is a burrowing animal commonly associated with loose sandy loam soils and stabilized dune habitats. Although uncommon, this species has also been found in oak woodland sites, areas that provide dense vegetative ground cover, or under surface objects such as leaf litter, logs, and rocks. Impacts due to fire would be the loss of these cover habitats and increased solar exposure (higher ground temperatures) due to canopy loss.

***Diadophis punctatus modestus*. San Bernadino Ringneck Snake**
Ringneck snakes are infrequently found in coastal sage scrub, chaparral and grassland habitats in the Santa Monica Mountains. It is not known what the effects fires would have on these species, but these species are rarely found in the open and spend most of the time under logs and rocks, or in crevices.

***Lampropeltus zonata pulchra*. San Diego Mountain King Snake**
Mountain king snakes are infrequently found in riparian oak woodlands, and in narrow canyons with associated coastal sage scrub and chaparral habitats. Fire effects are not currently known, but loss in habitat would have an impact on the distribution of this species.

***Salvadora hexalepis virgultea*. Coast Patch-nosed Snake**
Coast patch-nose snakes are commonly found in the steep canyons of the Santa Monica Mountains and specifically associated with rocky outcrops. There are no known affects due to fire on this species.

***Thamnophis hammondii*. Two-striped Garter Snake**
Two-striped garter snakes are commonly seen in intermittent and perennial streams with rocky beds in the Santa Monica Mountains. Impacts on these species from fire would be siltation of stream habitats and loss of vegetative cover.

- Amphibians

***Bufo microscaphus californicus*. Arroyo Southwestern Toad**
There are no records of Arroyo southwestern toad in the Santa Monica Mountains.

***Rana aurora draytonii*. California Red-legged Frog**
Red-legged frogs have been extirpated from the Santa Monica Mountains. A small population was recently discovered in the eastern end of the Simi Hills and is in danger of extinction from urban encroachment. Fire effects on these species is the loss of riparian vegetation and canopy cover, and siltation of deep pools from sedimentation and erosion as a result of the loss of hillside vegetation.

***Taricha tarosa tarosa*. Coast Range Newt**
Newts are a commonly found species in steep rocky canyons and creeks in the Santa Monica Mountains. Although semi-aquatic during certain times of the year, newts do require upland habitats in which to hibernate during the fall and winter. There is one study in the Santa Monica Mountains of fire impacts on newts following the 1993 fires (Kirby and Kats, 1996). Although no decline in adults was observed, sedimentation of pool habitats reduced breeding habitat and breeding success.

- Fish

There are two federal endangered fish species in the Santa Monica Mountains, *Eucyclogobius newberryi* (tidewater goby) and *Oncorhynchus mykiss* (southern California steelhead trout). Tidewater gobies are strictly an estuarine species found in the lagoons of Malibu and Topanga. Steelhead trout are an anadromous species which return to Malibu, Topanga and Arroyo Sequit to spawn. Developing fry return to the ocean following large rain events that allow passage into the ocean where they mature for the next few years before returning to natal streams. Impacts of fires on these species would be impacts due to sedimentation of spawning sites.

IV Natural Resources

B Geology and Soils

Geology

Tectonic History

The transverse ranges have been formed as the result of compressive forces between the Pacific and North American tectonic plates. The Santa Monica Mountains are considered to be a large symmetrical anticline formed by north-south compression generated at the Big Bend of the San Andreas fault. The east-west orientation of the transverse ranges was created when the Transverse Ranges were rotated counter 90 degrees clockwise in the last 15 MYBP (Harden, 1998).

Tectonic forces are ongoing today and the transverse ranges are one of the most rapidly uplifting areas in the world. Movement along faults causing uplift of the Santa Monica Mountains have an average of 0.30 to 1.0 mm/year along the Malibu Coast and Santa Monica faults, respectively (http://www.consrv.ca.gov/cgs/rghm/psha/ofr9608/index). Quantum increases in elevation can occur during major earthquake events. For example the Santa Susana Mountains were raised 70 cm during the 1994 Northridge earthquake (Harden, 1998).

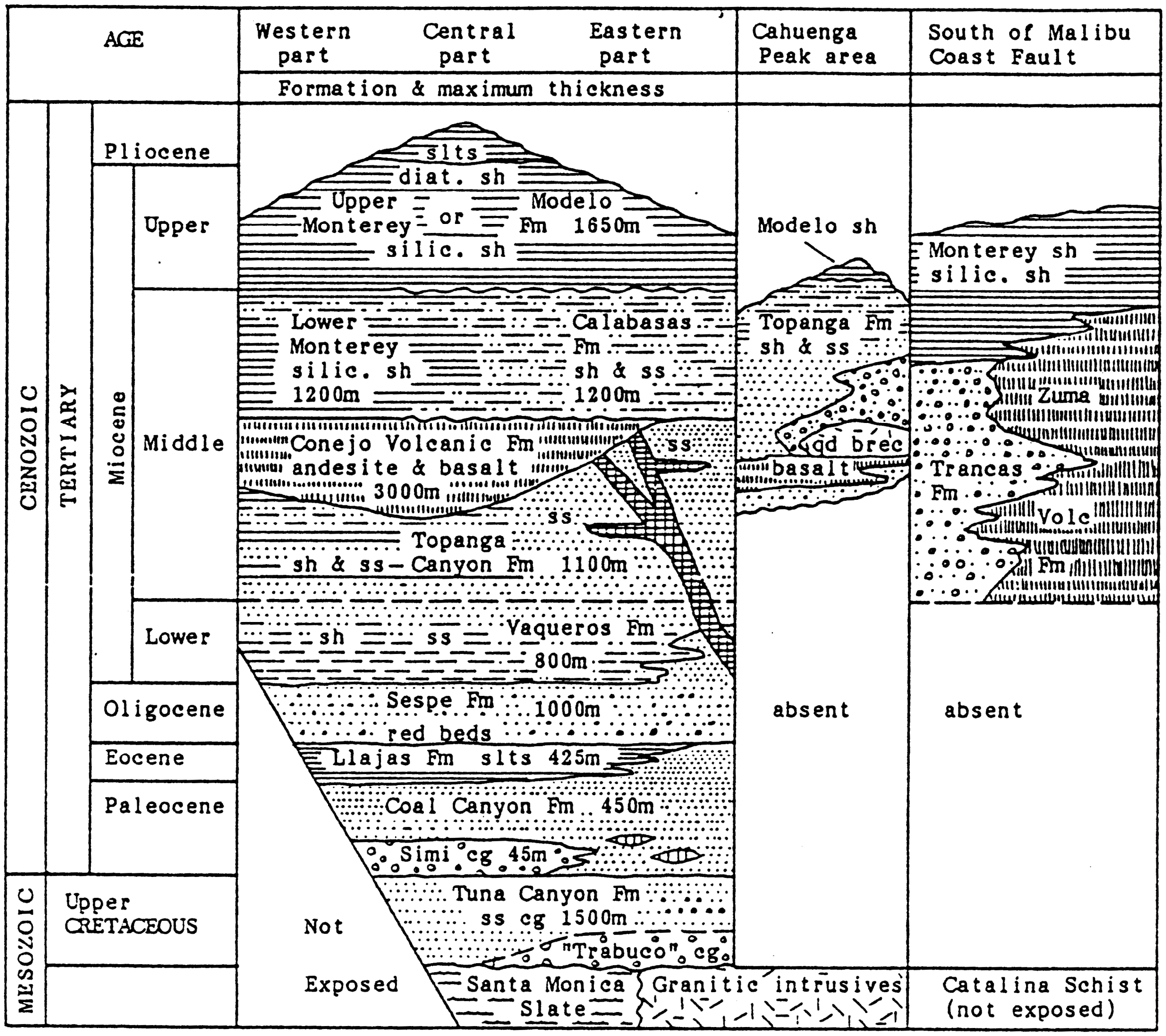
Erosion Cycle

The Santa Monica Mountains are in the early to mid-maturity stage of the present erosion cycle, as indicated by its steep sided, V-shaped canyons and the sharpness of most of its ridges. However, there are also subdued, flattened ridges which indicate that the present erosion cycle was preceded by an earlier erosion cycle that reached late maturity stage when this range was reduced to low relief and was lower than it is now (Dibblee, 1982). Renewed uplift raised this range to its present height and is now causing it to undergo severe erosion in its present cycle. Numerous landslides on the southern slope and on high, steep, inland ridges (Yerkes et al, 1970; 1980) are indicative of rapid uplift. The lowland area north of the Santa Monica Mountains has been reduced to the late maturity stage of the present cycle as indicated by low rounded hills, floodplains along the parts of most canyons and by small valleys such as the Conejo Valley. The Simi Hills are in the midmaturity stage of the present erosion cycle.

Stratigraphy

The Santa Monica Mountains and their offshore extensions are the most geologically diverse of the mountain ranges within the transverse range province (Norris and Webb, 1990). The mountains are a complex assemblage of marine and non-marine sedimentary rocks, igneous intrusion and volcanic extrusive rocks. The topographical relief is the result of differential erosion and plate tectonics (e.g. uplifting, folding, and faulting). Geologic maps of the Santa Monica Mountains include Kew (1924), Hoots (1930), Durrell (1954), Truex and Hall (1969), Yerkes and Campbell (1980), Campbell et al. (1996), and the Dibblee Geological Foundation maps (1990-93). The location and associated time scale of the Santa Monica Mountains stratigraphy is diagrammed in Figure 3-25. The following is a generalized discussion of the rocks from oldest to youngest.

Figure 3-25 Stratigraphy of the Santa Monica Mountains (From Raven et, 1986, P 8)



The Santa Monica Mountains have a granitic and metamorphic basement more similar to the Sierra Nevada than to the Franciscan basement rock of the Santa Ynez Mountains and coast ranges. The oldest rocks in the Santa Monica Mountains are the Santa Monica slates, a metamorphosed marine sedimentary rock of middle Mesozoic age (Raven et al., 1986). They comprise about a fourth of the surface area of the Santa Monica Mountains and are made up of slates and schists of fine grained mica that also include minute grains of quartz and feldspar. The slates make up the basement rocks for the western and central Santa Monica Mountains and are exposed extensively in the range, east of Topanga Canyon. In many places the slate has been altered to phyllite and fine grained schist by contact metamorphism induced by granitic intrusions (Raven et al., 1986).

Granitic intrusives were formed during the Mesozoic when igneous intrusions, similar to those that produced the massive granitic batholiths in the Sierra Nevada occurred (Norris and Webb, 1978). These granitic intrusions also formed the basement rocks of the eastern Santa Monica Mountains. They are exposed northwest of Hollywood and around Cahuenga Peak. They are primarily composed of highly weathered quartz diorite and granodiorite (Raven et al, 1986) suggesting that they formed over a subducting oceanic plate.

During and following the period of granitic intrusions, the slates were uplifted and then gradually eroded until the late Cretaceous. Locally, terrestrial rock formations exist which were deposited over the eroded slates indicating erosion was sub-aerial (above sea level). Subsequently the sea again covered the majority of the land and a period of continuous deposition began as the spreading sea deposited conglomerates, sandstone and shale. The late Cretaceous, thin Trabuco formation (found in the eastern portion of the mountains) represents non-marine deposition, consisting primarily of clayey conglomerates. The marine Tuna Canyon formation includes deposits of turbidites (marine sandstone), slate, siltstone and conglomerates. This fossiliferous formation contains foraminifera, mollusks and ammonites.

It is possible that the non-marine Simi Conglomerate, found in the western portion of the mountains also has a late Cretaceous age, but current literature suggests an early Paleocene age. It represents a basal conglomerate overlying late Cretaceous rocks. The Simi Conglomerate indicates the processes of primary uplift, erosion of elevated formations, and marine deposition continued during the Cenozoic era (65MYBP- present).

The marine Coal Canyon formation is among the earliest formations from this era and represents a period of extensive marine deposition during the Paleocene and possibly earliest Eocene (65-38 MYBP) that resulted in marine shale, conglomerate, sandstone, siltstone, and limestone. These sediments accumulated to a maximum thickness of 8,500 feet. Some fossils, characterized by the gastropod Turritella pachecoensis, occur in the Coal Canyon formation.

The marine Llajas formation formed during the Eocene above the Coal Canyon formation in the western and central portions of the mountains. It consists of sandstone, pebbly conglomerate and fine grained shaly siltstones and mudstones.

From the late Eocene to the early Miocene (36-24 MYBP), portions of the Santa Monica Mountains were again above sea level and terrestrial floodplain deposits of up to 3,500 feet deep were formed. This distinctive Sespe formation consists commonly of “red-beds,” of sandstone, mudstone, and conglomerates. The flood plain discharged into a shallow marine basin. As sea level fluctuated, the Sespe formation interfingered with the marine Vaqueros Formation which was deposited in an adjacent shallow sea. This condition persisted until the upper Oligocene (23 MYBP), when sea level began to rise, submerging the site of the present Santa Monica Mountains. At this time changes also began in the Pacific and North American plate movements from convergent to right lateral shear which caused a shift in the topography of southern California from a marine shelf adjacent to a subduction zone, to the ridges and basins present today (Vedder and Howell, 1980).

Throughout the lower to middle Miocene (24-13 MYBP), thick sedimentary deposits accumulated in the marine and non-marine basins forming the Vaqueros formation and Topanga Group of rocks. The Vaqueros Formation consists of near shore sandstones and deeper water (up to 200 meters) siltstones. The Topanga Group consists of non-marine sandstones and mudstones of the Topanga Canyon Formation overlain by volcanic rocks of the Conejo Volcanics which in turn are overlain and interfingering with siltstones and sandstones of the Calabasas Formation. During the middle Miocene there was a period of massive volcanic activity in the region of what is currently the western Santa Monica Mountains that interrupted and co-existed with the sedimentary phase. Intrusive and extrusive volcanic activity also occurred in the region of the eastern portion of the range. These Conejo Volcanics are composed of alternating layers of andesitic and basaltic flow-breccias, agglomerates, mudflow-breccias, flows, pillow-breccia and aquagene tuffs indicating that much of the erupting lave was submarine (Raven, Thompson and Prigge, 1986 from Yerkes and Campbell, 1979). The Conejo Volcanics are exposed extensively in the western part of the Mountains, but exist only in a few locations east of Topanga Canyon.

The sandstone, siltstone and sedimentary breccias of the Calabasas formation were deposited in the late-middle Miocene in the same basins and at the same time as the later Conejo Volcanics. As a consequence, volcanic and sedimentary rocks are often interbedded.

Following deposition of the Topanga Group, the basins continued to develop with deep water sediments deposited in the late Miocene. An additional 4500 feet of marine diatomite, shale, sandstone, chert and basal conglomerate were deposited to create the Modelo formation. These episodes during the late Miocene represented some of the greatest encroachment of the sea in the vicinity of Ventura and Los Angeles.

The stratigraphy of the area south of the Malibu coast fault differs from the rest of the Santa Monica Mountains (Yerkes and Campbell, 1979). This area includes the coast west of Carbon Canyon and east of Nicholas Canyon. The Trancas formation and Zuma Volcanics are middle Miocene formations that were apparently deposited in a separate basin from rocks north of the fault, but are generally similar in age to the Calabasas Formation and Conejo Volcanics. These formations occur here but do not occur in the rest of the range. These unique formations are overlain by the widespread Monterey formation. The Trancas formation is a mixture of sedimentary marine rocks, including sandstone, mudstone, and claystone. A member of the Trancas formation, locally called the San Onofre Breccia is well exposed at Lachusa Point and surrounding Broadbeach area. The Zuma Volcanics consists of basaltic and andesitic flows, breccias, pillow lavas, mudflow breccias and aquagene tuffs.

The Monterey formation is named for outcrops in Monterey County, but are also well exposed along the coast south of Monterey to Palos Verdes Penninsula. They consist of blond to white colored, thinly bedded diatomaceous to clayey shales with interbedded sandstone. Although local school children call the diatomaceous shales “chalk rock,” it is actually formed of microorganisms with silica skeletons rather than calcium carbonate.

Beginning in the late Pliocene (5-1.8 MYBP), the Santa Monica Mountains began to be uplifted. Their present form is the result of ongoing uplift and erosion (Dibblee, 1982). At this time the rocks that form the Santa Monica Mountains were within a chain of islands within a Pliocene sea located at the latitude of Baja, California. Vedder and Howell (1980) estimated that the Pliocene ocean basin was nearly 4900 feet deep at the western end of what is currently the mountain range (Ventura) and up to 8200 feet deep near southeastern end of the range (Los Angeles). Thick beds of shale, sandstone and clay continued to accumulate. The Pico formation, characteristic of this period, has a maximum thickness of about 1000 feet. In the Pacific Palisades, where deep canyons have been cut through the thick Pleistocene alluvium, Pliocene rocks – soft claystone, siltstone and sandstone – are exposed (Raven et al., 1986).

In the early Quaternary, the range was re-elevated and the area has remained in a dynamic erosional-uplift cycle. This cycle has resulted in extensive alluvial fan deposits surrounding the Santa Monica Mountains in the Los Angeles Basin, San Fernando Valley and Oxnard Plain and fluvial sand and gravel deposits along major stream courses. On the south side of the mountains, remnant sandy marine terraces at Malibu Creek and Point Dume represent former shorelines. Three marine terraces are recognized in the range and from oldest to youngest are the Corral, Dume, and Malibu terraces. Uplift of the Santa Monica Mountains continues today at the rate of 0.3mm per year based on Marine terrace elevations. Uplift occurs as a direct result of plate tectonic compression, manifested as the numerous small and occasional large earthquakes felt in southern California. Erosive processes (e.g. landslides, gullying, debris flows, etc.) are the converse result of this rapid uplift.

Soils

Soil Classification

Ten general soil associations and consociations have been mapped in the Santa Monica Mountains by the Natural Resources Conservation Service (National Resource Conservation Service, in preparation). These include the following:

General Soil Map Units

1) Camarillo-Pacheco-Sulfic Fluvaquents Association	0-2% slopes
2) Chumash-Boades-Malibu Association	30-75% slopes
3) Cotharin-Talepop-Rock Outcrop Complex	30-75% slopes
4) Mipolomol-Topanga Association	30-75% slopes
5) Zumaridge-Sumiwawa-Rock Outcrop Association	30-75% slopes
6) Linne-Los Osos-Gaviota	30-75% slopes
7) Cropley-Urban Land Complex	0-15% slopes
8) Balcom-Xerorthents-Gazos Complex	2-75 % slopes

9) Cumulic Haploxerolls-Fluvaqents Association 0-9% slopes

10) Urbanland-Xerorthents, Landscaped Complex 0-9% slopes

These soil groupings can be identified by the geomorphic areas in which they occur. The first geomorphic grouping, corresponding to soil unit 1, is the outwash plain of Calleguas Creek, which occurs in the extreme western area of the park near Point Mugu Naval Air Station. These generally are level, somewhat poorly to poorly drained soils that formed in alluvium from mixed rock sources. These areas are currently in the tidal floodplain of Mugu Lagoon or are in use as a military facility.

The second geomorphic grouping includes the drainages and axial stream floodplains within the mountains themselves. This grouping corresponds to soil unit number 9. These are gently sloping, moderately well to well-drained soils that formed in alluvium, residuum and colluvium from sedimentary rock sources and/or basic igneous rock sources.

The third geomorphic grouping is the basic igneous hills and mountains such as Sandstone Peak. This grouping corresponds to soil unit number 3. These are moderately sloping to very steeply sloping, well-drained soils that formed in residuum and colluvium from basic igneous rock sources.

The fourth geomorphic grouping is the non-marine sedimentary shale and sandstone hills and mountains such as Castro Peak and Laguna Peak (soil unit numbers 2, 4 and 5). These are moderately sloping to very steeply sloping, well-drained soils that formed in residuum and colluvium from shale and sandstone.

The fifth geomorphic grouping is the marine sedimentary shale and sandstone hills, such as the Simi Hills. This grouping corresponds to soil unit numbers 6 and 8. These are moderately sloping to steeply sloping, well-drained soils that formed in residuum and colluvium from marine sediments.

The sixth geomorphic grouping is the Malibu Plain and other ocean terraces and alluvial fans adjacent to the ocean. This grouping corresponds to soil unit number 7. These are the gently to moderately sloping, well-drained soils that formed in alluvium from mixed rock sources.

The last soil unit, number 10, includes urban areas, golf courses, landscaped areas and is comprised of houses and adjacent landscaped areas.

Previous soil information for the Santa Monica Mountains includes data completed by the Ventura County Soil Survey (SCS, 1970). This survey identified and mapped the following 14 soil associations:

1) Pico-Metz-Anacapa

2) Mocho-Sorrento-Garretson

3) Camarillo-Hueneme-Pacheco

4) Riverwash-Sandy Alluvial-Coastal Beaches

5) Rincon-Huerhuero-Azule

6) Ojai-Sorrento, Heavy Variant

7) San Benito-Nacimiento-Linne

8) Castaic-Balcom-Saugus

9) Calleguas-Arnold

10) Gazos-Santa Lucia

11) Millsholm-Malibu-Los Osos

12) Sespe-Lodo

13) Sedimentary Rock Land-Gaviota

14) Hambright-Igneous Rock Land-Gilroy

Soils 1 through 4 can be classified as having moderate to level slopes, excessively to poorly drained soils on alluvial fans, plains and basins. They are primarily derived from sedimentary rocks and to a lesser extent from basic igneous rocks. Annual grasses, forbs, brush, and scattered oak trees are their dominant vegetation. In the Santa Monica Mountains, Hidden Valley soils match these characteristics.

Soils 5 and 6 can be described as being located on level to moderately steep slopes and being well drained to moderately well drained. Most of these soils formed from alluvium derived from sedimentary rocks on old terraces. A few derive from alluvial fans. Soils from association number 5 can be found in the Simi Hills portion of the SMMNRA.

Soils 7 through 14 make up most of the rest of the Santa Monica Mountains and Simi Hills. These soils can be classified as being found on moderate to very steep slopes and are well drained to excessively drained upland soils. They may be shallow to very deep over somewhat consolidated sediments, sandstone, shale or basic igneous rocks.

The following additional soil associations were mapped in Los Angeles County and constituted the remaining portions of the Santa Monica Mountains (SCS, 1969):

10) Oceano

24) Perkins-Rincon

27) Gaviota-Millsholm

28) Hambright-Gilroy

34) Diablo-Altamont

35) Altamont-Diablo

36) San Andreas-San Benito

42) Rock Land-Rough Broken Land

Soils of the Oceano Association occur on nearly level slopes, and are excessively drained and wind eroded. They are derived from wind-blown sands and have a thin surface layer (accumulation of organic matter). In the Santa Monica Mountains, these soils are found at the tip of Point Dume.

Soils of Perkins-Rincon Association have zero to 15 percent slopes, are well drained and are located on terraces to 500 feet. They occur along the Pacific Coast Highway from Leo Carrillo State Beach to Trancas Canyon.

Soils of the Gaviota-Millsholm Association occur on steep mountainous upland terrain from 100 to 3500 feet. They are somewhat excessively drained and are derived from shattered shale or fine-grained sandstone. In the Santa Monica Mountains, they occur in a band from Leo Carrillo State Beach north to Castro Crest and south to Las Virgenes and then spread out toward Topanga Canyon Road. East of Topanga Canyon, they are found in a band that includes the peaks stretching toward San Vicente Mountain and Interstate 405 south of the Encino Reservoir.

The Hambright-Gilroy Association makes up the greatest portion of Los Angeles County within the Santa Monica Mountains. These soils have 15 to 50 percent slopes, are well drained and are derived from basic igneous rock. They extend through the middle portion of the Santa Monica Mountains from the Ventura County line through Saddle Peak eastwards and occur in pockets along Topanga Canyon and Corral Canyon.

Soils of the Diablo-Altamont Association occur on rolling foothills, and are relatively deep and well drained. These soils are derived from strongly calcareous shale. In the Santa Monica Mountains, they occur beyond the tip of Point Dume.

Soils of the Altamont-Diablo Association have steep eroded slopes and, as a result, compared to those of the Diablo-Altamont Association have reduced depth and water-holding capacity. In the Santa Monica Mountains, they occur north of Highway 101 along the Ventura County line and north of the reverse association above Point Dume.

The San Andreas-San Benito Association soils occur on steep to very steep mountainous terrain up to 1500 feet. They are somewhat deep, well-drained and are derived from sandstone. In the Santa Monica Mountains, they occur from Topanga Canyon Road east to Interstate 405, except where the band of Gaviota-Millsholm soils occurs along the peaks.

Rock Land-Rough Broken Land occurs on strongly sloping to steep mountainous upland. This miscellaneous association is characterized by very shallow soils and rocky outcrops that cover 50 to 90 percent of the area. In the Santa Monica Mountains this association occurs at Brents Mountain in Malibu Creek State Park and other rocky areas near the Ventura County line and at Topanga Lookout.

Soil movement

The Santa Monica Mountains are naturally prone to landslides due to an unstable combination of rapid uplift, steep slopes and often poorly cemented sedimentary rock. In general, the more rapid the uplift in an area, the greater the gravitational forces that trigger earth movements (landslides and erosion). Mass wasting through landsliding and erosion are necessary to keep up with tectonic uplift; soil erosion, landsliding, and debris flows/debris torrents are normal and necessary processes in tectonically active areas of the world. These events can not be stopped and have created the habitable landscape features of the Santa Monica Mountains and the surrounding Ventura and Los Angeles basins (Spittler, 1995).

The erosional process moves sediment from hillside slopes to stream channels and ultimately to the ocean. Sediment from hillsides moves into stream channels through the processes of debris avalanches (hillside debris flows), dry flows (dry ravel), and sheet and rill erosion. Sediments in stream channels can be transported as suspended loads, bed loads, or as debris torrents (channel debris flows) (Spittler, 1995). Destructive debris avalanches are created by soil slips or by progressive sediment bulking of surface runoff by dry ravel materials accumulated in steeply inclined U- or V-shaped topographic depressions on hillsides.

In the Santa Monica Mountains, hillslope erosion is primarily a result of surface runoff and particle entrainment during and immediately after precipitation events and secondarily of dry ravel between winter precipitation events and during the long dry summers. Debris flows occur when rains are intense, frequent and persistent and can quickly provide abundant sediment to stream channels, transforming normal floods to mudflows (Campbell, 1975). The rate of erosion is a combined function of precipitation, slope, aspect, vegetation and soil type (Orme et al., 2002). Soil movement in the form of rockfalls and deep-seated landslides can occur many days or weeks after rainfall events and is more related to the nature of the underlying geological formation.

Fire Effects on Soil Movement

Vegetation provides slope stability and reduces erosion through interception of rainfall, litter, structural support of loose material, roots that reinforce the soil, and soil communities that create soil structure (Spittler, 1995). Vegetated slopes have high rates of infiltration and very little overland flow. When vegetation is removed through fire, erosion increases, peak flows in channels occur more rapidly, and the flood peaks are higher. The amount and form of post-fire erosion varies dramatically depending on the seasonal timing, duration and intensity of precipitation in the first three years following fire. The amount of erosion is also related to percentage of watersheds burned and the intensity of the fire.

Hillslope erosion

Following the 1993 Old Topanga and Green Meadow fires, localized hillslope erosion rates were monitored with .5 m^2 plots at burned and unburned sites (Orme et al., 1996). The total amount of erosion was determined to be a complex function of precipitation amount and precipitation intensity or duration. A geomorphic threshold was identified where erosion increased more rapidly above 18 degrees slope angle with increases in precipitation. Moister north-facing and more exposed west-facing slopes tended to have higher rates of erosion. Post fire dry ravel was a significant component of the total sediment yield.

The overall erosion pattern seen on burned hillsides was significantly influenced by the rainfall patterns that occurred in the 3 years following the fires. The rainfall was less than average in the first year post-fire, very high in the second year post-fire and average in the third year post-fire. Low intensity, gentle-moderate rains fell in November-January, which favored infiltration versus overland flows, germinated cover, and allowed resprouting prior to more intense February-March rainfall. No rills were observed on burned slopes until the moderate storms of February-March, when sheetflow and rill formation was observed in burned areas but not the unburned areas. Year-1 initial erosion from burned sites was 25-50 times the rate on unburned sites following moderate to heavy storms. In year-2, the erosion rates decreased to 10 times the control site in very heavy rains and in year-3, the erosion rates were only twice the control rate. The cumulative erosion rates over the three year period show the expected peak of increased erosion in the first year; in the second year vegetation has not sufficiently recovered to prevent erosion with the severe storms of that year and the total erosion increased to 1.5 times the amount generated in the first year; in year-3, despite storms of greater intensity than in the first year, total erosion decreased to ⅓ the amount generated in the first year (Orme et al., 1996).

Clearly the erosion yield from any burned area is dependent on a complex interaction between an unpredictable rainfall pattern and vegetation recovery. The underlying soil type is also a primary determinant of erosion yield both as it affects intrinsic soil erosion rates and vegetation productivity and recovery rates. Unlike the sites that had largely recovered within 3 years post-fire, very high erosion rates (4 – 14 g/m^2/ day following precipitation events) were still observed seven years after the 1993 fire in the Red Rock area of Topanga on steep north and west facing slopes underlain by coarse clastic sediment (Orme et al., 2002).

Fire severity also affects the amount of sediment delivered to stream channels through erosion. Riggan et al. (1994) reported that moderately burned watersheds discharged 3/8 the amount of sediment of severely burned watersheds.

Debris flows

Four types of debris flows occur in the Santa Monica Mountains following fires: soil slips, progressive sediment bulking of surface runoff by dry ravel materials, mobilization of materials from pre-existing landslides, and road cut failure. Soil slip debris flows occur more often in areas underlain by igneous rock than in areas of sedimentary rock. Both sediment bulking and soil slip triggered debris flows occur in areas of sedimentary rock. Most post-fire debris flows are in 0- and 1st –order drainages (Menitove et al., 1999).

Southern California post-fire debris flows have been classified into two types based analysis of 86 drainages following fires in 1997 (Cannon, 1999). Type-1 debris flows have high discharges, consist of poorly sorted, up to boulder size materials, and are highly destructive. They most commonly occur in drainages underlain with sedimentary rocks, and are generated from drainages 5-10 degrees steeper than drainages that produce only stream flow. Type-1 debris flows are initiated by progressive sediment bulking of surface runoff, but also by debris from soil-slips. Most occur in watersheds without a water repellent hydrophobic layer which therefore allows greater water infiltration. Type-2 debris flows consist of unsorted sand and gravel sized material in an abundant, organically rich matrix and are produced in drainages underlain by crystalline rocks. They generally transport smaller material, inundate smaller areas, and are less destructive than Type-1 flows. The Type-2 debris flows are associated with soil slip failures on hill slopes and are more often produced from drainages having a water repellent soil layer. Post-fire debris flows are most commonly the first response to storms, followed by more dilute flows in the same event. In this study, no debris flows were produced from burned watersheds following the initial erosive event.

Areas that are potentially susceptible to hazardous Type-1 post-fire debris flows can be identified on the basis of bedrock materials, slope, fire intensity, soil hydrophobicity, and analysis of alluvial fan materials at the mouths of creeks (Spittler, 1995). The threshold precipitation values required to generate post-fire debris flows have been reported to be on the order of 1.5-2.0 mm rain/5 min (Riggan et al., 1994).

Mass movement from soil slips also occurs in the Santa Monica Mountains in unburned watersheds. In the absence of fire, mass movement occurs as soil slips that transform downslope to debris flows especially on grass dominated slopes underlain by mudstone or claystone. The threshold values include slopes greater than 20 degrees, total storm precipitation exceeding 300 mm (12”) and sustained intensities exceeding 25mm/hr (1”/hr) (Raphael et al., 1995; Campbell, 1975). Soil slips are seven times as likely to occur on grass-converted slopes than on shrub dominated slopes (Rice et al., 1969).

Channel effects: flooding

Following fire, the water storage capacity of the soil mantle is reduced by 20 times or more (Wells, 1981). With rainfall, peak flows in channels occur more rapidly than in unburned watersheds and the flood peaks are higher. This reduces the size of the storm necessary to surpass the critical stream power necessary to mobilize stored sediment and create debris torrents. A forty fold increase in sediment production can occur during the first storm season following a fire if high intensity rainfall occurs (Bruinton, 1982). The sediment from debris flows to stream channels can transform normal floods into non-Newtonian (Bingham) flows.

Debris flows commonly exceed the levels of predicted floods because they have up to 2.5 times the volume of floods consisting of water alone, and they tend to drop sediment in critical locations such as culverts, buildings, stream channels and roads. Federal Insurance Management Plan (FIRM) floodplain maps do not take into account debris flows, which can exceed the elevations of water-based flows and can rapidly change channel geometry. However, the Los Angeles County Department of Public Works, in its Hydrology and Sedimentation Manuals, 1991, identifies the soil types and debris and sedimentation formation relative to the rainfall zone that can calculate storm flows in various watersheds.

Channel effects: sediment transfer and stream morphology

Watersheds in the Santa Monica Mountains comprise a spatial system within which an erosional –depositional cascade erodes sediment from hillsides and then moves it to stream tributaries, then to the mainstream and eventually to the ocean. Sediment is normally transported through the stream channel in episodic periods of erosion and deposition starting with steeper slopes then moving to lower gradient stream reaches, immediately downstream. Sediment moves rapidly through steep lower mainstem reaches, and is rarely deposited until it reaches gentler gradients immediately before and at the stream mouth. There are frequent opportunities for storage within the system and sediment rarely reaches a tributary in one event unless debris flows occur (Orme et al., 2002).

The size and quantity of channel sediments that can be transported increases as the volume and velocity of the stream flow increases. If high intensity storms occur in burned watersheds where the critical power of the stream exceeds that needed to mobilize the sediment stored in it, the sediment is mobilized as debris torrents. Debris torrents form a thick slurry of water, soil and rock. With water content of about 450%, these debris flows have tremendous weight, and are so viscous that they can carry boulders several feet in diameter. However, moderate storms are more common than high intensity storms and normal fluvial transport of stored sediments is more likely to occur than large magnitude, high intensity debris torrents (Florsheim et al., 1991). When convergence of high intensity storms on fire or vegetation converted slopes does occur however, exceptional mass movement takes place. These dramatic events create extraordinary stream discharge rates and sediment yields and lead to exceptional channel geometry changes (Orme and Bailey, 1971).

Post-fire erosion control measures

Post fire seeding is not effective on steep chaparral hill slopes where the timing, energy and magnitude of the soil movement processes will overcome any resistive power of germinating non-native grass seeds. For major storms in the first season following a fire, grass seeding will not reduce flood peaks and will have no effect on dry ravel or sediment from stored channel alluvium. There is some limited possibility that grass seed might reduce rilling if the seed were to germinate and grow in time to provide adequate cover and if the resistance power of grass were to exceed the erosive power of rill formation. However, Keeley (1998) has shown that cover from post-fire native vegetation far exceeds that from aerial seeding of non-native seed mixes, and native regeneration therefore provides much more effective erosion control than application of non-native seed mixes.

Soil Nutrient Cycling

Chaparral

Chaparral soils are typically nutrient deficient, particularly in nitrogen, and limit plant productivity (Rundel, 1986; Christensen, 1994). Foliar leaching of nitrate and atmospheric deposition may provide a nutrient pulse following the first winter rain. In the absence of fire, litter fall is the most important means of returning nutrients to the soil (Gray and Schlesinger, 1981). Litterfall is concentrated in the summer and is relatively rapid (Schlesinger and Hasey, 1981). Presumably in response to the selective pressure of nitrogen limited soils, a number of chaparral shrubs have nitrogen fixing symbiosis, e.g., *Ceanothus spp., Myrica spp.*, *Lotus scoparius*, *Cercocarpus betuloides*, and *Pickeringia montana*.

As a powerful and instantaneous modifier of the environment, fire can change the form, distribution and amounts of nutrients (Wan et al., 2001). Fire recycles nutrients tied up in plant matter, therefore, soil levels of most nutrients increase after fire (Christensen and Muller, 1975). Fire increases soil $NH4^+$ and $NO3^-$. The increase in $NH4^+$ is highest immediately after the fire and decreases asymptotically to pre-fire levels over time. The increase in $NO3^-$ is small immediately after fire, but peaks 7-12 months after fire, and decreases to pre-fire levels within 5 years (Wan et al., 2001).

It is widely accepted that fire decreases the total nutrient pool due to post-fire runoff and volatilization of nitrogenous compounds in plant material and soil organic matter (DeBano and Conrad, 1978; Keeley, 2000). It is estimated that nitrogen losses from volatilization are on the order of 6kg/Mg of fuel consumed (Christensen, 1994) which is directly related to the temperature or intensity of the fire (DeBano and Conrad, 1977). Nitrogen losses from a moderate intensity fire in chaparral would be 133-178 lbs nitrogen/acre (Rundel, 1986). These amounts are small relative to the total soil nitrogen pool. For example, fire induced nitrogen loss of 65kg/ha in Arizona chaparral accounts for 5% of the total 1300kg N/ha in the upper soil layer (0-10 cm) (DeBano et al., 1998). The long-term effects of fire variables such as frequency and intensity on chaparral ecosystem nitrogen is not known.

Nitrogen replenishment from normal atmospheric inputs from dry and wet deposition are on the order of magnitude of <10lbs/10,000 sq. miles /year (Rundel, 1986). This amount is clearly inadequate to replace the amount of nitrogen lost to fire volatilization. Although fire reduces total nitrogen pool, post-fire conditions are favorable for growth because a larger amount of inorganic nitrogen is available that can be used directly by plants. The flush of post-fire ephemerals immobilizes and stores a large pool of nitrogen that could be lost through erosion or leaching. Symbiotic nitrogen fixation by shrubs and herbaceous legumes provides critical replacement of the nitrogen pools in the early years following fire (Rundel, 1986; Christensen, 1994). In urban areas of southern California nitrogen inputs to adjoining wildland areas from pollution sources are estimated to be ten times natural levels (Rundel, 1986). This has potentially significant long-term effects on the nitrogen cycle and the chaparral ecosystem.

It is unlikely that the site degradation and vegetation conversion that has been observed in chaparral stands with high fire frequencies is due to loss of soil nutrients from fire. Annual grasses typical of degraded or type converted habitats require soils with relatively high nutrient levels and are competitively excluded where nutrients are bound up in well-established native vegetation or where sites are naturally low in nutrients. Type conversion is better explained as the demographic consequence of obligate seeding species' failure to recruit under a short fire-return interval than as a soil nutrient phenomenon. Nor do old stands of chaparral become unproductive due to nutrient limitations (Schlesinger et al., 1982; Keeley, 2000). Studies of plant growth that have compared stands a decade or two after fire with stands nearly a century old have repeatedly failed to find any evidence of declining productivity (Keeley, 2000).

Riparian woodlands and shrublands

The riparian zone is not nutrient limited (Faber et al., 1989). Nutrients from coastal sage scrub and chaparral on upland slopes are carried by streams and accumulate on floodplains, banks, and coastal wetlands. One riparian species, *Alnus rhombifoli*a, also has the ability to fix atmospheric nitrogen. Following fire, non-wetable charcoal and ash carried in overland and stream flows, settle and remain in sediment deposits, available for use in plant growth. Riparian corridors provide a unique function in nutrient cycling to link nutrients between upland areas and downstream plant communities (Faber et al., 1989).

Fire effects on soils

The effect of fire on soil depends upon the type of soil (i.e., its chemical and structural properties), the moisture content of the soil, the type and total biomass of the vegetation growing on the soil, as well as the temperature and duration of the fire passing over the soil. Soil heating during fire depends on fire intensity and duration and the amount of moisture in the soil. In general, the direct effects of soil heating are limited to the upper 2-3 cm of soil (DeBano et al., 1979). In areas of extensive fuel accumulation, smoldering fires can heat the soil to 10-20 cm resulting in considerable chemical change and soil sterilization. Except where soil heating is extreme, physical changes in physical features such as texture or mineralogy are negligible. The extent of soil organic mineral loss is directly related to fire intensity. Fire alters the hydrologic properties of soils in chaparral. Soils in chaparral accumulate organic hydrophobic compounds in the soil layer during interfire years. The heat of the fire distills the hydrophobic compounds down through the soil profile, creating a hydrophobic seal with a wettable layer, 1-5 cm thick, overlying a water repellent soil layer. The hydrophobic layer potentially creates conditions for sheet erosion above the hydrophobic seal (Christensen, 1994). It has been reported that the hydrophobic layer rapidly breaks down after fire due to gopher and ant activity which creates conduits for surface water through the repellent layer (Spittler, 1995).

IV Natural Resources

C Water Resources/Wetlands

The coastal Santa Monica Mountains include both fresh water and marine water resources. Because of the dry Mediterranean climate of southern California, fresh water resources are both spatially and seasonally limited, and are therefore especially valuable. In addition to water quality, other important values associated with water resources are plant and wildlife habitat, and recreational opportunities.

The largest watershed located completely within the Santa Monica Mountains Zone is the Malibu Creek watershed. It is 105 square miles and contains a total of 225 stream segments within six major drainages (Medea Creek, Triunfo Creek, Cold Creek, Malibu Creek, Las Virgenes Canyon, and Potrero Valley). The Malibu Creek watershed drains the north slopes of the Santa Monica Mountains, the south slopes of the Simi Hills, the interior valleys between the two ranges, and the Malibu Canyon drainage. The remainder of the Santa Monica Mountains watersheds (17%), are a series of parallel, north-south canyons that drain the southern slopes of the mountains. Each of the major north-south canyons has a stream with associated riparian vegetation lining it. In addition, there are a large number of east-west trending drainages on the slopes of these canyons. Figure 3-3, on page 3-6, shows the streams and watershed boundaries within the SMMNRA.

Most streams in the Santa Monica Mountains are typically intermittent (seasonally flowing) streams. This is particularly the case in watersheds on the south facing slopes of the Santa Monica Mountains, where steep gradient canyons flow directly into the Santa Monica Bay. There are only a few exceptions in which year round flows occur: Solstice Canyon (which is perennial due to geological formations and tectonic forces that push the water table to the surface), and larger watersheds such as Topanga and Malibu Canyons. These steep gradient canyons, although seasonal are not completely dry. In many canyons where the stream channel meets bedrock, small pool habitats are formed. Even in drought years (year 2002) there are sites where water percolates to the surface. These areas are ideal places for amphibious and aquatic life. Many of the semi-aquatic amphibians, *Hyla regilla*, *Hyla cadaverina*, and *Taricha tarosa* (California species of special concern) breed in these habitats.

In the larger watersheds (Arroyo Sequit, Topanga, and Malibu Canyons) pool habitats are also areas in which developing southern steelhead, *Oncorhynchus mykiss* (federally threatened) fry take refuge until fall and winter rain events allow for an opportunity to disperse into the ocean. Malibu and Topanga Canyons are particularly valuable in that they are perennial and provide habitat for breeding adults as well. The arroyo chub, *Gila orcutti* (species of special concern), is also found in Malibu Creek. The only other perennial flowing creek is Solstice Creek and the National Park Service is currently working on the removal and modifications of in-stream barriers to allow for re-establishment of steelhead populations.

A high diversity of wildlife and plant species is associated with the streams of the Santa Monica Mountains. In addition to the amphibians and fish discussed above, the fresh water springs, seeps and surface waters are necessary for a diverse array of aquatic insects, reptiles, birds, rodents, and large mammals. These include the southwestern pond turtle, California slender salamander, California newt, Monterey ensatina, arboreal salamander, California toad and Pacific tree frog. The mammalian wildlife, which requires the fresh water for drinking includes carnivores such as mountain lions and bobcats, as well as coyotes and deer.

Although riparian plant communities make up less than 1% of the area of the Santa Monica Mountains, 20% of the total flora is found in these stream-associated habitats (Rundel, 1998). Riparian corridors include sycamores (*Platanus racemosa*), oaks (*Quercus agrifolia*), remnant populations of big leaf maples (*Acer macrophyllum*), cottonwoods (*Populus sp.*) and alder (*Alnus rhombifolia*).

Wetlands

From Mugu Lagoon to the Santa Monica Pier, the SMMNRA includes 41 miles of Pacific coastline. The coast includes two major lagoons, Mugu Lagoon and Malibu Lagoon, that are a vital stop on the Pacific Flyway, provide habitat for a variety of rare or threatened species (e.g., California least tern, brown pelican, Belding's savanna sparrow, and the tidewater goby), spawning grounds for grunion (*Leuesthes tenuis*) and other small fish, a breeding ground for the harbor seal, and habitat for rare coastal plant communities. Mugu Lagoon, is owned by the U.S. Navy and is the largest, relatively undisturbed salt marsh in southern California. The other lagoon, Malibu Lagoon, is at the outlet of the 105 square miles of the Malibu Creek drainage. Smaller estuarine areas are located at the mouths of Topanga Canyon, Trancas Creek, and Zuma Creek.

Threats to Malibu and Mugu Lagoons are landform alteration, urban runoff including elevated levels of nutrients (such as phosphorous and nitrogen), pathogens, toxicants (e.g., heavy metals), litter and trash, alien plant species, and heavy sediment loads.

Recreational Use of Water Resources

The recreational uses of the water resources in the SMMNRA are extremely varied and include both marine and freshwater areas. The shoreline of the SMMNRA receives some of the most intense recreational use in the United States and is an extremely popular summer destination for residents of Ventura and Los Angeles Counties, as well as for visitors from all parts of the United States and other countries. Direct contact recreation at the beaches includes swimming, surfing, scuba diving, snorkeling, bathing, tidepool visiting, and water play. The non-contact water recreation for ocean areas includes fishing, boating, sailing, whale watching, surf fishing, sun bathing, picnicking, and beach sports such as volleyball. In the freshwater areas, direct contact activities include swimming and water play. Freshwater non-contact activities include fishing, nature walks, picnicking, birding, and sailing model boats.

The beaches are used most heavily in the summer. During the remainder of the year, upland areas are used more than the beaches. Visitation in the fall, winter, and spring months is not as great as in the summer, but there is never a time when visitors are absent.

Fire Effects on Water Resources

Water quality, nutrient, and temperature effects

Fire leads to short–term impacts on water quality, the degree of impact being related to erosion and sedimentation rates caused by storm severity and fire intensity. Riggan reported that severe fires produced 1.7 times the concentration of $NO3^-$ as moderate fires (Riggan et al., 1994). Fire effects on water quality include increases in stream sediment with consequent increases in turbidity, temperature, and level of dissolved organic nutrients (Tideman, et al., 1979). In general, most organic components of plant biomass are volatilized during combustion, while inorganic compounds (Ca, Mg, Na, K) fall to the soil surface in ash. These inorganic cations can be carried to solution into streams during precipitation and increase levels of these inorganic elements to above normal levels.

Nitrate and phosphate concentrations increased two-to three-fold above normal runoff levels in Malibu Lagoon immediately after the 1993 Old Topanga Canyon Fire and rain events.

Associated effects on biota were limited and were attributed to changes in physical stream parameters from sedimentation and not to changes in water chemistry. The lack of adverse biological impacts from the increased nutrient loading was due to the open connection between the lagoon and the ocean, a seasonal phenomenon for all southern California coastal streams, which breach the sand berm barriers that separate them from the ocean with the coming of major winter storms. Under the normal pattern of fall fires followed by winter storms, the immediate impacts of fire on water quality appear to be transitory, with relatively minor biological impacts (Lin, Suffet, and Ambrose, in press). However in the rare event where a summer fire is followed by an atypical late summer storm, the potential for excess nutrients to create eutrophic conditions exists if the resulting stream flow is inadequate to breach the sand berm. Under these rare circumstances the potential exists for adverse water quality impacts to aquatic organisms in coastal embayments.

Other effects due to fire are the loss of canopy cover. The loss of vegetative cover in riparian areas and adjacent communities result in drier and hotter conditions. These conditions result in the loss of amphibian microhabitats and warmer water conditions which reduce the viability of developing steelhead eggs and larvae. An increase in ultraviolet exposure from canopy loss may also have adverse impacts on certain amphibian species that are unable to repair UV damage.

Sedimentation and debris flows

Loss of vegetative cover from fire leads to increased rates of hillside erosion which is ultimately deposited as sediment in stream channels. In high intensity storms large quantities of sediment have the potential to be mobilized as debris flows (hillside movement) and debris torrents (stream channel movement) (see page 3-96, Soil Movement). In addition to the direct effects caused by deposition of large quantities of sediment in the stream channel, debris torrents have the potential to create long term changes in stream morphology caused by the flows' extreme erosive forces.

Debris flows will have the biggest impacts on aquatic wildlife as a result of siltation and alteration of pool habitats (Kerby and Kats, 1996). Loss of pool habitats, will have the largest impacts on developing steelhead fry and amphibian larva. Siltation is temporary, as scouring from subsequent rain events will re-establish these habitats. Effects on steelhead and amphibians will not have permanent effects. All amphibians are partially terrestrial and not obligated to these pool habitats. Also, species such as the newt (*Taricha tarosa*) can live up to 20 years, and will re-occupy pool habitats as they are recreated in subsequent years. Steelhead are opportunistic spawners and will return to streams as episodic rain events re-establish stream flows and re-create pool habitats, although, a generation or two may be excluded by stream siltation following fire.

IV Natural Resources

D Coastal Resources

The California coast is enriched by upwelling that brings nutrient-laden waters up from depth. This allows rocky reefs along the coast to support lush giant kelp forests, considered to be one of the most productive ecosystems in the world. The Malibu coastline of the Santa Monica Mountains National Recreation Area has significant amounts of rocky bottom substrate with kelp forests and is considered to be one of the richest and most productive marine habitat areas in southern California (Ambrose et al., 1996).

Fire Effects on Coastal Resources

Kelp beds experience cyclical periods of population growth and decline that varies by season and year. Factors that influence kelp distribution and abundance are oceanic climate cycles such as El Nino, suspended sediments (light), available rock substrate, and wave action from major oceanic storm events. Sedimentation from major storm events following fires has the potential to bury rocky marine substrate. Loss of rocky bottom is considered to be a significant impact because it is a loss of regional biodiversity due to the less productive nature of sandy bottom habitat and the limited distribution of rocky bottom habitat (Ambrose et al., 1996).

In comparison to the Palos Verdes peninsula, the other major kelp habitat area in Santa Monica Bay, there has been a net decline in kelp habitat along the Malibu coast in the last 20 years. The kelp declines in Malibu have been attributed to sediment effects (Smith et al., 2002). In comparison to the Palos Verdes peninsula, the Malibu coast has less sand and relatively greater amounts of clay and silts in the bottom sediments, and greater total amounts of total suspended sediments in the water column.

It has not been determined if the source of greater suspended sediments in the water column is due to re-suspension of bottom sediments or to terrestrial erosion and whether the lower amount of rock substrate is due to increased sedimentation rates from terrestrial sources in the Santa Monica Mountains versus those in the Palos Verdes peninsula. If sediment sources from the land are affecting the amount of rock substrate or suspended sediments, then, the pulse of sediments from post fire years with high rainfall may be an additional contributing factor to the fluctuation in kelp bed distribution and population size.

IV Natural Resources

E Paleontological Resources

Paleontological resources are evidences of life preserved in a geologic context. These non-renewable resources include fossil vertebrates, invertebrates, paleobotanical specimens and other traces of life including burrows, nests, and trackways. Fossil resources provide an insight into the history of life on earth and have phenomenal educational and scientific values. Threats to paleontological resources include natural effects such as rates of erosion and climactic impacts as well as human influences of theft, vandalism, and construction.

Paleontological resources in the Santa Monica Mountains include isolated fossil specimens, fossil sites, and fossil bearing rock units. The paleontologic sensitivity of the SMMNRA varies across the landscape depending on local geology as well as geomorphic factors. The geology and depositional history of different rock units, in turn, largely determines the potential for yielding fossil remains. The following is a summary of the known fossil bearing rock formations in SMMNRA.

The oldest paleontological resources of the SMMNRA come from the Late Cretaceous Chatsworth formation. Ammonites, extinct mollusks related to the chambered nautilus, have been collected from this formation, as well as marine foraminifera, clams, snails, bryozoans, and shark teeth. A substantial portion of the Cenozoic period (the last 65,000,000 years), the Santa Monica Mountains area has been the site of marine deposition. There are a number of tertiary rock units in the mountains known to yield scientifically significant paleontologic resources (e.g., Modelo, Pico, and Topanga formations). The sediments of the Modelo formation contain microfossils, clams, bony fish, whales, and algae. Bryozoans, gastropods, sharks, and cetaceans have been recovered from fossil sites in the Pico Formation. The Topanga formation, a shallow-water, marine sandstone unit, has yielded bony fish, bivalves, and gastropods.

Less sensitive are the extensive deposits of colluvium mantling the hills of the SMMNRA, as well as the alluvium of the outwash fans issuing from the canyons. In contrast, fine-grained (clay to fine sand) valley fill deposits have yielded the remains of a diversity of extinct Pleistocene land mammals. Recent discoveries in southern California of quaternary-age fossil plants entombed at the base of landslides have provided important new information on the ecological history of the region (e.g., Axelrod, 1988), and have been used to determine that this important phenomenon is distinctly episodic (Reneau et al. 1986).

Fire Effects on Paleontological Resources

Fire has the potential to directly impact surface fossils where heat may fracture fossil rock. This is believed to be a relatively minor impact, however. Fossil resources are more likely to be damaged by heavy equipment in fire control operations. Fossil resources may be exposed after wildfire and therefore be susceptible to theft or vandalism. The most serious impact to fossil resource may occur with heavy post-fire erosion.

IV Natural Resources

F Air Quality

Congress recognized the significance of the Santa Monica Mountains, situated between the highly developed Los Angeles Basin, the San Fernando Valley, and the Oxnard Plain, in the recreation area's enabling legislation. Public law 95-625 specified that

> *"...the Secretary shall manage the Recreation Area in a manner which will preserve and enhance ...its public value as an air shed for the southern California metropolitan area."*

Since the 1940's, air quality measurements taken adjacent to the Santa Monica Mountains in urban Los Angeles have been among the worst in the United States. The South Coast is in extreme non-attainment for ozone, serious non-attainment for carbon monoxide, and serious non-attainment for small particulate matter under 10 microns (PM10). The South Coast Air Quality Management District (SCAQMD) and Ventura County Air Pollution Control District (APCD) function as the oversight organizations for monitoring air quality and compliance with standards. Atmospheric circulation patterns influence the intensity of smog in southern California. The development of strong temperature inversions, which inhibit vertical air mixing, occurs especially during the summer months. In the presence of temperature inversions, visibility is greatly decreased and pollutants are trapped close to the ground in the basins of the Los Angeles metropolitan area. Lower air quality occurs during the summer due to the combination of persistent, strong inversion layers with intense solar radiation, which increase the photochemical reactions that contribute to the amount of ozone produced. During the winter, lower weakened inversion layers, a result of less intense solar radiation, dissipate during winter afternoons as direct solar radiation reaches a peak and heats the ground surfaces, causing air to rise, creating convective air currents.

Air quality in the vicinity of the Santa Monica Mountains varies widely as a result of physiography, climatological conditions, the location or presence of an inversion layer, distance from the coast and the amount of pollutants emitted into the atmosphere. Overall, coastal areas experience better air quality than inland interior valleys and the Santa Monica Mountains exhibit better air quality than the surrounding urban landscape. As a result of air quality standards instituted with the California Clean Air Act, air quality has improved in the Los Angeles area since monitoring began (SCAQMD, 1993).

Ecological Impacts of Air Quality

The ecological effects of poor air quality in the Santa Monica Mountains are not well known, although it is clear from studies in other parts of southern California that declining air quality does impact native plant communities. For example, pollutants contribute to nitrogen deposition on foliage, which in turn can favor the invasion of natural communities by exotic plants and also causes a decline in water quality. This has been a significant problem in coastal sage scrub areas in other parts of southern California. In the Santa Monica Mountains, prevailing winds keep the air relatively clean, so similar impacts are likely not as severe. However, more research is necessary to definitively ascertain these and other ecological impacts from air pollution in the SMMNRA.

Regulatory Overview

The SMMNRA, is a Class II area under the Federal Clean Air Act (CAA, as amended), located in Ventura and Los Angeles counties. Ventura County is part of the South Central Coast Air Basin under the authority of the Ventura County Air Pollution Control District (APCD). Los Angeles County is part of the South Coast Air Basin under the authority of the South Coast Air Quality Management District (AQMD). The APCD and AQMD are the governing authorities with primary responsibility for controlling air pollution sources in Ventura County and Los Angeles County, respectively.

National Ambient Air Quality Standards

The CAA requires the Environmental Protection Agency to identify national ambient air quality standards (NAAQS) to protect public health and welfare. Standards have been set for six pollutants: ozone (O3), carbon monoxide (CO), nitrogen dioxide (NO2), sulfur dioxide (SO2), particulate matter less than 10 microns (PM10) and less than 2.5 microns (PM2.5), and lead (Pub). These pollutants are called criteria pollutants because the standards satisfy criteria specified in the act. An area where a standard is exceeded more than three times in three years can be considered a non-attainment area subject to planning and pollution control requirements that are more stringent than areas that meet standards. Ventura County is in attainment or is unclassified for all federal ambient air quality standards except ozone, and exceeds California state air quality standards for ozone, carbon monoxide and particulate matter. Los Angeles County does not meet federal or state standards for ozone, carbon monoxide and particulate matter.

State Implementation Plan

Ventura County APCD and South Coast AQMD are responsible for developing a State Implementation Plan (SIP) for federal and state pollutants for which they are not in attainment. The SIP defines control measures that are designed to bring areas into attainment. Basic components of a state implementation plan include legal authority, an emissions inventory, an air quality monitoring network, control strategy demonstration modeling, rules and emission limiting regulations, new source review provisions, enforcement and surveillance, and other programs as necessary to attain standards. Emission sources are broken into four main categories: stationary, non-road mobile, on-road mobile, and biogenic.

Ventura County Air Quality Monitoring

Ventura County air has dramatically improved over the years between 1973-2000, although the federal standard for ozone is still exceeded. Progress has been steady and, overall, the air is getting cleaner year by year. Pollutants are being emitted into the air at a lesser rate, but the weather dictates if the pollutants will disperse or accumulate.

Los Angeles County Air Quality Monitoring

In a continuing trend of significant long-term improvement in air quality in the South Coast Air Basin, the year 1999 recorded a new low in ozone concentrations. However, maximum pollutant concentrations in the region still exceed the federal standards for ozone, carbon monoxide, and particulate matter (PM10 and PM2.5) by a wide margin.

Santa Monica Mountains National Recreation Area

There are no ambient air quality monitoring sites within the boundaries of the SMMNRA. The SMMNRA depends on local district monitoring sites for air quality information. A 1998 emissions inventory of pollutants is available for the SMMNRA where stationary, area, and mobile source emissions within the park were calculated. Particulate matter (PM), sulfur dioxide (SO2), nitrogen oxides (NOx), carbon monoxide (CO), and volatile organic compounds (VOCs) were estimated for stationary and area sources within the SMMNRA. Stationary sources include fossil fuel-fired space and water heating equipment, fireplaces and wood stoves. Area sources include prescribed burning and campfires. Mobile emission sources in SMMNRA include highway and non-road vehicles and equipment. Particulate matter (PM), nitrogen oxides (NOx), carbon monoxide (CO), and volatile organic compounds (VOCs) were calculated for mobile sources. When compared to regional emissions SMMNRA air pollution emissions are negligible (SMMNRA GMP, Tables 31, 32, and 33 in the Air Quality Tables and Figures appendix). The majority of air pollution in the SMMNRA is transported from mobile sources outside the park, especially from Los Angeles County and the surrounding area.

Conformity Rule

Section 176 of the Clean Air Act requires that federal actions conform to State Implementation Plans (SIP) for achieving and maintaining the national standards. Federal actions must not cause or contribute to new violations of any standard, increase the frequency or severity of any existing violation, interfere with timely attainment or maintenance of any standard, delay emission reduction milestones, or contradict SIP requirements. The conformity rule applies only in federal non-attainment areas. Conformity applies to activities in SMMNRA because Ventura County exceeds the federal ozone standard and Los Angeles County exceeds federal standards for ozone, carbon monoxide, and particulate matter.

Fire Effects on Air Quality

Periods of the worst air quality within the Los Angeles metropolitan area may coincide with weather conditions which favor fuel-driven wildfires. There have been a number of air quality incidents in which high levels of hydrocarbon emission related pollution have been supplemented with particulate debris from severe forest fires in the mountains surrounding the populated inland basins.

Poor air quality conditions also coincide with live-fuel moisture conditions that are favorable for prescribed burning. In general, prescribed burns will affect local air quality for short periods of time on the burn day, with air quality returning to normal levels once the burning is completed. Particulate matter is the primary air pollutant from prescribed burns, and may cause short term localized impacts on visibility or serious health effects to sensitive individuals.

The use of prescribed fire for land management purposes is regulated by the State Air Resources Board under the jurisdiction of the South Central Coast Air Quality Management District (Ventura County Air Pollution Control District) and the South Coast Air Quality Management District in accordance with the conformity rule. Smoke emitted by prescribed fire and its dispersal characteristics are determined by the techniques used in the application of prescribed fire, and the weather conditions present at the time of the burn. The use of backing fires, wind patterns that disperse smoke away from sensitive areas, fuel moisture conditions which promote rapid burnout, and good smoke management plans, all help limit the air pollution contributions from prescribed fire.

Air quality problems may occur when other local agencies conduct prescribed burns that occur simultaneously with NPS prescribed burns. There are a limited number of local air quality management district permitted burn days that occur in conjunction with weather and fuel moisture conditions conducive to prescribed burning. The chances of more than one agency conducting prescribed burns on the same day are high. Inter-agency co-ordination through the local air quality management districts is required to insure that local air quality standards are not impaired by prescribed burning activities.

V Cultural/Historic Resources

Historical Overview of the Santa Monica Mountains Region

The Santa Monica Mountains have been at the center of complex human interactions for thousands of years. The richness and diversity of the region's cultural resources reflect the density and diversity of human population in the mountains over time.

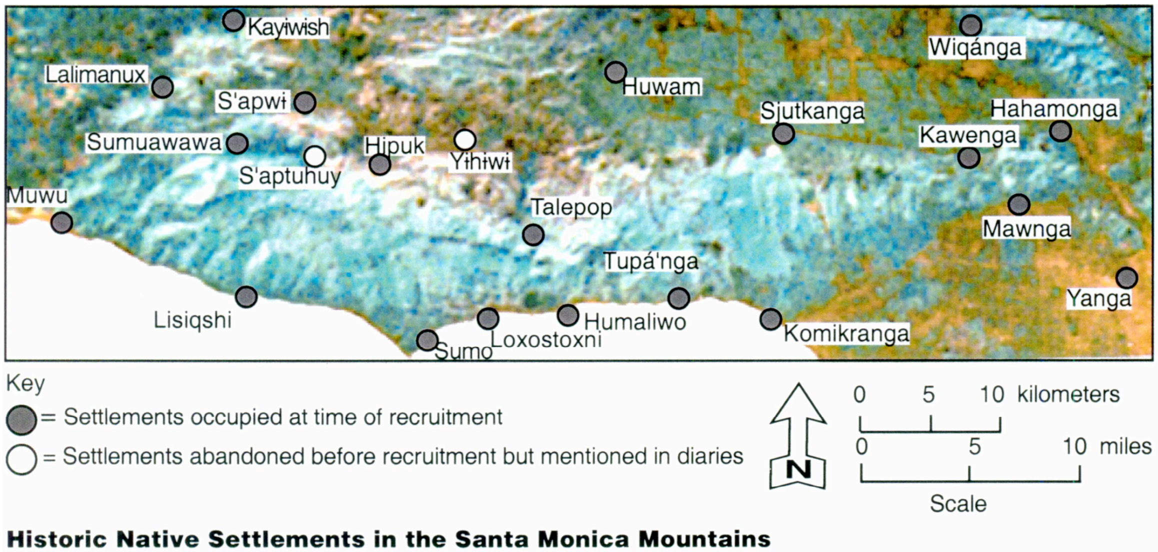
The Chumash and Gabrielino/Tongva

At historic contact, the Santa Monica Mountains were occupied by Native Americans of two tribal affiliations: Chumash and Gabrielino/Tongva (King, 2000). While speaking languages of different families, marriage records of the Spanish Missions document significant social interactions between the Chumash and Gabrielino/Tongva. Likewise, the two groups shared a number of common cultural traits. The following summaries of Chumash and Gabrielino/Tongva culture are summarized from King (2000) and references therein.

Chumash

The Chumash held much of the south-central California coast, including the northern Channel Islands, as well as inland portions of the Coast and Peninsular ranges. The Santa Monica Mountains comprised the southernmost extent of Chumash settlement (Figure 3-26). The Chumash were subdivided into several geographically distinct linguistic divisions, and those Chumash occupying the Santa Monica Mountains were known as Ventureno. The Chumash population ranged from 15,000 to 20,000 people, perhaps 1300 of whom resided in the Santa Monica Mountains region. Archeological and linguistic data suggest that the Chumash culture may have evolved in place for more than 9000 years.

Figure 3-26 Historic Native Settlements in the Santa Monica Mountains



The village was the center of Chumash life. A typical Chumash village contained several houses (sheltering five or six occupants each), sweat and menstrual lodges, and a cemetery. Food stores, processing implements and wealth items were also kept there. Historical records document at least six coastal and 10 interior Chumash villages in the Santa Monica Mountains region. Village populations ranged from perhaps 15 to 400 individuals, and coastal villages were, on average, somewhat larger than those of the interior. Each village had associated resource extraction sites in its respective territory, although it was likely that most inhabitants returned home each evening. In addition, the Chumash recognized shrines within the Santa Monica Mountains region, and many natural features on the landscape were named.

At historic contact, the Chumash did not practice traditional agriculture, relying instead on the great diversity of plant, animal, and insect life found in the Santa Monica Mountains region. Those villages along the coast were particularly adept at the extraction of marine resources, including dozens of fish species, marine mammals, and a variety of mollusks. The take of marine resources was facilitated through the use of large redwood plank canoes, which allowed for utilization of offshore species. The remains of marine resources also occur in archeological sites in the interior of the Santa Monica Mountains, suggesting trade with coastal inhabitants.

Terrestrial resources were also of great importance to the Chumash of the Santa Monica Mountains. Animals utilized included large mammals (deer and pronghorn), small mammals, reptiles, and various birds. Plant foods assumed particular significance among the Chumash, with bulbs and roots of yucca, small seeds, acorns and other nuts, fruits, and greens being the chief staples. The Chumash had extensive knowledge of the seasonal availability of plant foods, and were able to harvest virtually year-round.

Although not traditional agriculturalists, it is a mistake to assume that the Chumash simply relied on the natural reproductive potential of the terrestrial resources upon which they subsisted. Instead, the Chumash engaged in a variety of resource management activities, of which fire was the most important. Intentional burning was conducted in order to spur the growth of desired plant species, facilitate hunting, reduce fuel loads, and many other purposes.

Spanish accounts documented the Chumash as being extremely socially and politically complex, especially when compared to other non-agricultural societies. Chumash society was heirarchically organized and many political positions were ascribed. The chief was the central authority of the political system, and most villages had one or more chiefs. Particularly influential chiefs could control large areas and numerous villages. For example, a paramount chief residing at the village of Humaliwo had jurisdiction over a large part of the Santa Monica Mountains. Such wide-ranging influence was facilitated by an extensive network of kinship ties. Chiefs were charged with managing stores of food, caring for the impoverished, hosting fiestas, and administering activities within the village territory. Two messengers served each chief, and relayed information between villages. An individual called a paxa trained and initiated members of the secret men's society 'antap. The paxa and members of 'antap society were usually members of high ranking families, and assisted the chief in hosting social gatherings.

Spanish accounts also document a high degree of industriousness among the Chumash. Manufacture of certain items of wealth, such as shell beads and plank canoes, probably fell in the hands of various specialists. The Chumash of the Santa Monica Mountains specialized in the manufacture of arrows for the adjacent Gabrielino/Tongva, and perhaps stone mortars as well. The Chumash and their neighbors maintained a brisk trade in shell beads, food, and other goods.

Gabrielino/Tongva

At European contact, the territory of the Gabrielino/Tongva encompassed the Los Angeles Basin, portions of the adjacent mountain ranges and the southern Channel Islands, including the easternmost Santa Monica Mountains (Figure 3-21). The Gabrielino/Tongva residing in the Santa Monica Mountains were members of a distinct Western Tongva group, whose territory also included the southern San Fernando Valley, southern Channel Islands, downtown Los Angeles and San Pedro. Mission registers indicate that the Western Tongva rarely intermarried with Gabrielino/Tongva residing east of the Los Angeles River. On the basis of archeological and other evidence, the Gabrielino/Tongva appear to have arrived in the region between 2500 and 3000 years ago.

Nine historic Western Tongva villages have been identified in the Santa Monica Mountains region. Most of these villages were located in the interior, and populations ranged from about 10 to 360 inhabitants.

Subsistence practices among the Gabrielino/Tongva were similar to those of the Chumash, with extensive utilization of both marine and terrestrial resources. The material culture of these groups was also comparable, including use of redwood plank canoes by the Gabrielino/Tongva.

The Gabrielino/Tongva social organization mimicked that of the Chumash with hereditary chieftainship and religious authority delegated to ceremonial managers (also called paxa or paha) of secret dancing societies. It appears that political and ritual organization may have been more important for organizing behavior among the Gabrielino/Tongva than the economically driven Chumash.

Gabrielino/Tongva cosmology was dictated by an all-powerful god Tcangitngic, who brought misfortune to those unwilling to comply with his moral authority. Oral traditions among the Gabrielino/Tongva reveal heavy emphasis on political authority, law and spiritual position.

The Spanish Era

Sporadic Spanish contact with the Santa Monica Mountains and its native inhabitants began in the 1500's with exploratory voyages along the Pacific coast. Although Spain claimed Alta California as part of its empire, sustained Spanish presence in the region was not established until the late 1700's. Three Franciscan Missions – San Gabriel (founded in 1771), Ventura (founded in 1782), and San Fernando (founded in 1797) – drew native converts from the Santa Monica Mountains. Mission records indicate that the majority of Santa Monica Mountains Chumash were baptized at Ventura, while Western Tongva were drawn exclusively to San Gabriel and San Fernando. Native Americans of the Santa Monica Mountains region submitted to conversion from the late 1700's and through the early 1800's. Generally speaking, the farther a village lay from a mission, the later in time its inhabitants abandoned their aboriginal territory. Los Angeles Pueblo, a secular settlement established in 1781, also served an important economic and social role in the region.

Religious conversion and abandonment of traditional villages was largely voluntary. Native Americans were enticed to the missions for the opportunity to exploit new religious, social, political, and economic opportunities. The Spanish were eager for converts not only to satisfy Christian doctrine, but also the critical need for a labor source to perform agricultural tasks, domestic chores and other duties. In exchange, Native Americans were fed, clothed, sheltered, and given a Christian education. Conversion, however, meant abandonment of many traditional cultural practices and rapid knowledge loss. Those failing to comply with the restrictions of the new lifestyle could be harshly punished. In addition, the crowded Mission environment promoted the rise and spread of infectious diseases against which native populations had no or little immunity, and resulted in very high mortality rates.

In an effort to strengthen its hold on Alta California, Spain offered land grants to private citizens for economic development. These ranged from hundreds to many thousands of acres in size. Seventeen such grants were established within and adjacent to the Santa Monica Mountains, most of which served as cattle ranches (or ranchos). Local Native Americans were quick to relocate to ranchos and find employment as cowboys or vaqueros; abandonment of several villages in the Santa Monica Mountains between 1770 and 1800 (prior to Mission recruitment) might be attributable to this phenomenon.

The Mexican Era

When Mexico, whose territory included the American West, won its independence from Spain in 1821, Mexican officials and land speculators pressed for the distribution of mission property. During the 1820's and 1830's, the Mexican government passed legislation to both diminish the influence of the Franciscans and distribute mission lands to settlers, and by 1834 all of the mission lands were secularized and opened to occupation. In addition, the Mexican government continued the Spanish practice, begun decades earlier, of granting private individuals large tracts of land.

Like Spain, however, Mexico could not sustain its hold upon the vast American West. In 1848, United States military forces defeated those of Mexico, and the subsequent Treaty of Guadalupe Hidalgo ceded more than 500,000 square miles of territory, including Alta California, to the United States.

California Statehood to the Present

News of gold discovered in California swept across the nation in 1848, and Americans rushed west to find it. In 1850, California was admitted to the Union and San Francisco, Sacramento, Stockton, Los Angeles, and San Diego began to take form as cities. American emigrants to California also discovered vast tracts of land either occupied by Native American Indians or held by rancheros, and the uncertainties and confusion over the ownership and boundaries of the land required years to sort out.

Native American Indians had no legal rights to land in early California. Even though they were bound to the land by millennia of occupation, they were ousted from favorable lands, and in some instances, interned in reservations, modeled after the missions. Some California Native American Indians were massacred in their villages.

More troublesome to land acquisition for the new Californians, was the legacy of the Hispanic land claims associated with rancho concessions. In 1851, Congress passed the California Land Act, establishing a three-person Land Claims Commission and a complex legal mechanism to determine the legitimacy of Hispanic land claims. The indefinite boundaries of the unsurveyed landholdings, the lack of documentation in the possession of the claimants, and both the expenses of the legal fees and the time necessary to establish title in the courts, often delayed confirmation of landholdings, sometimes for decades. In addition, title to the former rancho concessions was frequently clouded by the host of American newcomers who, taking advantage of a process burdened with confusion and delay, simply settled on the land and were later looked upon favorably by the non-Hispanic courts.

By the 1870's, the demand for land in California prompted the subdivision of many of the larger landholdings. Since the latter decades of the 19th century, the rapid subdivision and re-subdivision of land, often punctuated by claims and counter claims, has been an enduring characteristic of much of the California landscape, including pockets of the Santa Monica Mountains.

During the 20th century, a favorable climate, water supplied from outside sources, agriculture, oil, the movie industry, and the burgeoning automobile industry facilitated the transformation of the Los Angeles basin into a megalopolis. Today, the greater Los Angeles metropolitan area is one of most racially and culturally diverse areas of the world and the Santa Monica Mountains are an island of open space amidst a sea of urbanization.

Cultural Resources of the Santa Monica Mountains Region

The NPS (1997) recognizes five types of cultural resources: archeological resources, structures, ethnographic resources, cultural landscapes, and museum objects. Archeological resources "are the remains of past human activity and records documenting the scientific analysis of these remains" (NPS, 1997:8). These include artifacts, ecofacts, and features. Structures "are material assemblies that extend the limits of human capacity" (NPS, 1997:8), and comprise such diverse objects as buildings, bridges, vehicles, monuments, vessels, fences, and canals. Ethnographic resources "are basic expressions of human culture and the basis for continuity of cultural systems" and encompasses both the tangible (native languages, subsistence activities) and intangible (oral traditions, religious beliefs) (NPS, 1997:9). The management of ethnographic resources entails the recognition that traditional cultures can have different worldviews and the right to maintain their traditions. Cultural landscapes "are settings we have created in the natural world" (NPS, 1997:8). They are intertwined patterns of natural and constructed features that represent human manipulation and adaptation of the land. Finally, museum objects "are manifestations and records of behavior and ideas that span the breadth of human experience and depth of natural history" (NPS, 1997:8). Examples of typical museum objects include field and laboratory notes, artifacts, and photographs.

Archaeological Resources

About 20 percent of NPS lands in the SMMNRA and an estimated 30 percent of the land throughout the Santa Monica Mountains have been surveyed for archeological sites. Archeological site density in the Santa Monica Mountains is very high, with more than 1500 known archeological sites, including 188 on NPS land, numerous resources on California State Parks and Santa Monica Mountains Conservancy owned land and another 1200 sites in the Santa Monica Mountains Zone. Of these, sites representing precontact and historic native occupations, as well as Euroamerican settlement have been documented.

Native American Archeological Resources
The great percentage of the recorded archeological sites in Santa Monica Mountains contain components attributable to Native American Indians. King (2000) identified several documented site types in the Santa Monica Mountains including: permanent settlements (villages), temporary camps, yucca ovens, bedrock milling features, rockshelters, lithic quarries, and pictographs. Two Chumash archeological sites in the Santa Monica Mountains — the village of Humaliwo, and Saddle Rock Ranch pictograph site — are listed on the National Register of Historic Places. In addition, at least two sites have been formally determined eligible, but are not yet listed; the vast majority of Native American Indian archeological resources have not been evaluated.

There has been no systematic monitoring of archeological sites over time in the Santa Monica

Mountains. However, the overall impression is that many extremely important sites have been lost to development but significant sites remain. Archaeological sites continue to be threatened by development, salvage archeology, private collectors, inadequate protections from the permit process, acid fog and rain, malicious vandalism, fire and fire suppression, and most importantly, erosion from fire, flooding, development, or earthquakes and landslides.

King (1990, 2000) suggested that the Santa Monica Mountains region was occupied by at least 11,000 years B.P., although direct evidence is scarce. The Early Period (8000 to 2200 years B.P.), marks the first preserved evidence of permanent settlements and cemeteries in the region. While most Early Period settlements appear to have been rather small, larger villages supporting several hundred inhabitants were also present. Stylistically, artifacts such as shell beads and ornaments changed little throughout the Early Period, although increased numbers through time is taken to reflect a growth in social complexity. Millingstones and handstones are common in Early Period sites, although mortars and pestles did not appear in appreciable numbers until 6,000 to 5,000 years B.P., suggesting adoption of an increasingly diverse diet. Marine fishing appears to have gained importance through the Early Period.

The Middle Period (2200 to 900 years B.P.) is signified by changes in ornaments and other artifacts and cemetery organization from the preceding Early Period that King (1990, 2000) took to reflect development of hereditary control of political and economic power. Middle Period settlement shifts, such as settlement in previously marginal zones and villages in locations with poor defensibility, are suggested to signify integration of villages into larger political units, as well increased economic integration.

Finally, the Late Period (900 to 150 years B.P.) saw the rapid development of new economic subsystems like those described by the Spanish. Populations aggregated into larger villages, which may have encouraged trade. Native groups intensively managed a wide variety of habitats, and many foodstuffs were traded to the Channel Islands, where terrestrial resources were scarce. Conversely, those villages in the interior valleys relied on marine resources transported from the coast. The absence of ritual objects in Late Period grave lots implies that religion was controlled by powerful institutions.

Although Chumash and Gabrielino/Tongva material culture was quite similar, some distinctions can be recognized in the archeological record. For example, cremation mortuaries occur only in the territories occupied by the Gabrielino/Tongva and related groups speaking Uto-Aztecan languages.

King (2000) suggested that other less conventional archeological remnants might also be found in the Santa Monica Mountains. For example, “fields” where crops of small seeds were actively managed with fire and other means might be recognizable through detailed soil analysis, including the recovery and identification of phytoliths. Furthermore, the modern distribution of vegetation may be indicative of past human management practices, and mapping economically important species such as yucca, wild cherry and oak useful for reconstructing resource procurement and use.

Based on analysis of historical, archeological and ecological data, King (2000) developed a set of archeological expectations for particular landforms and vegetation communities in the Santa Monica Mountains (Table 3-10). These might prove useful for predicting the locations and contents of archeological resources found in unsurveyed areas.

Table 3-10 Expected Archeological Indicators by Vegetation Community and Landform (Adapted from King 2000)

Setting	Archeological Evidence
Ridge Tops and Foothills	Yucca ovens, burned yucca and bulb parts; artifacts and features associated with hunting and camping; tools for making and maintaining traps; postholes of pole structures and house depressions
Open Areas at Junction and Foothills	Mortars and pestles; burned chia and other seeds; carand of Valleys bonized oak bark; postholes of pole structures and house depressions
Chaparral	Artifacts and features associated with hunting and camping; burned manzanita berries and seeds; burned islay hulls
Wetlands	Burned seeds of gathered seeds; carbonized oak bark; mortars and pestles
Riparian	Artifacts and features associated with hunting and camping; burned berries; carbonized acorn hulls and attachment scars; fire-altered rocks; structures
Beach	Bones of fish, shells and small mollusks; fishhooks and tools used to make and repair nets

Historical Archeological Resources

There were nearly 1300 homestead claims in the Santa Monica Mountains, though not all of the claims were improved and patented. As more archeological surveys are undertaken, more information regarding historic archeological sites will become available, providing important interpretive links to the settlement and development of the mountains during the 19th and 20th centuries.

Historic Structures

There are hundreds of structures in the Santa Monica Mountains and adjacent foothills that are considered to be of at least local historical significance. Some structures are significant because of the events that occurred there. Rancho Sierra Vista, for example, is important for its contribution to the development of agriculture in Ventura County, particularly cattle and horse raising and the introduction of citrus and avocado orchards. Other structures are significant because of their occupant, such as the Will Rogers House or the Adamson House. Still others are significant for their architectural style, representing the diverse artistry of such architects as Wright, Neutra, and Schlindler.

None of the missions established by the Spanish were within the boundaries of the SMMNRA. A few rancho era structures are within the boundaries, such as the Sepulveda adobe, as well as many structures built during the American homesteading and ranching era, such as the Chesebro Road (ca. 1880's).

Three structures within the SMMNRA's boundaries, but which are not on NPS lands, are listed in the National Register of Historic Places:

- **Adamson House and Grounds** – Erected in 1929, the Adamson House, located within Malibu Lagoon State Beach, is notable for its blend of Moorish and Spanish-Mediterranean architecture and the use of lavish tile art on floors and walls. In addition, the site's designed landscape reflects the long interaction between the house's inhabitants and the land. The house is significant for its association with a family who originally migrated to America in 1638 and whose descendants moved westward to California.
- **Looff's Hippodrome, Santa Monica Pier** – Looff's Hippodrome is a rare example of an early shelter built to house a carousel in an amusement park, and is one of only two such structures that remain on the west coast. The carousel in the Hippodrome is not the Looff carousel originally installed in 1916, when the Hippodrome opened. The present carousel is a Philadelphia Toboggan Company carousel built in 1922 and installed in the Hippodrome in 1947.
- **Will Rogers House** – Located in Will Rogers State Historic Park, this house was the home of noted American humorist, writer, and motion picture actor — Will Rogers. Many trophies, collections, and personal effects of Will Rogers are exhibited in the house. The house, which was built ca. 1926, and adjacent land was presented to the State of California in 1944, for use as a state park.

In addition, there are about 15 structures on NPS lands — at the Paramount, Rancho Sierra Vista and Peter Strauss Ranches — that are currently recorded in the recreation area's List of Classified Structures (Table 3-11).

Table 3-11 List of Classified Structures

Structure	LCS Number	National Register Status
Keller House	059749	Not Evaluated
Morrison Ranch House	059747	Not Evaluated
Paramount Movie Ranch – Equipment Storage Shed	059687	Eligible
Paramount Movie Ranch – Fire Patrol Station	059685	Eligible
Paramount Movie Ranch – Livestock Barn	059683	Eligible
Paramount Movie Ranch – Main Roads	059683	Eligible
Paramount Movie Ranch – Medea Creek Bridge	059689	Eligible
Paramount Movie Ranch – Mess Hall-Kitchen	059681	Eligible

Structure	LCS Number	National Register Status
Paramount Movie Ranch – Carpenter Shop	059682	Eligible
Paramount Movie Ranch – Prop Storage Shed	059684	Eligible
Paramount Movie Ranch – Prop Storage Shed	059686	Eligible
Peter Strauss Ranch – Amphitheater	059940	Eligible
Peter Strauss Ranch – Aviary	059939	Eligible
Peter Strauss Ranch – Entrance Arch	059932	Eligible
Peter Strauss Ranch – Guest House	059936	Eligible
Peter Strauss Ranch – Live Oak No. 6/Boundary Marker	059931	Eligible
Peter Strauss Ranch – Main House	059926	Eligible
Peter Strauss Ranch – Petting Zoo	059941	Eligible
Peter Strauss Ranch – Retaining Walls	057908	Eligible
Peter Strauss Ranch – Spillway/Bulkheads /Abutments	059942	Eligible
Peter Strauss Ranch—Stone and Concrete Terracing	059927	Eligible
Peter Strauss Ranch—Storage Shed	059937	Eligible
Peter Strauss Ranch—Swimming Pool	059933	Eligible
Peter Strauss Ranch—Terrazzo Dance Floor	059938	Eligible
Peter Strauss Ranch—Watchtower/Gatetower	059928	Eligible
Peter Strauss Ranch—Water Tank	059935	Eligible
Rancho Sierra Vista Barn	059748	Potentially eligible

The fire protection requirements of these buildings are significantly different from each other. Some of these buildings are along main highways, have unimpeded access and are highly visible. In contrast, some of the historic structures are relatively remote, otherwise hidden, and highly susceptible to damage and/or destruction by wildfire. In particular, the Morrison Ranch House is situated in an area of moderately dense natural vegetation and is located a considerable distance from the nearest paved road. Annual clearing of brush and grass immediately adjacent to the structures is performed annually by NPS maintenance staff.

Additional historic structures potentially eligible for the National Register

Structures on NPS lands:

- Arroyo Sequit (Mason) house
- Beal House at Rancho Sierra Vista

- Roberts shrine in Solstice
- Doheny house in Franklin
- Franklin Canyon Penstock
- Franklin Canyon WPA (Works Progress Administration) improvements
- Camp 8 structures
- Cheeseborough homestead site
- Cheeseborough historic road

There are many other structures potentially eligible for the National Register but are not on NPS land. These structures include:

- Structures on State Park lands
- Adamson House
- Will Rogers House, Barn and Polo field
- Stunt homestead site
- Danielson Home in Point Mugu
- Danielson hunting cabin and cemetary in Point Mugu
- Rancho Sierra Vista Ranch Center in Point Mugu
- Mr. Blanding's Dream House (Movie Set)
- Mott adobe (ruins)
- Malibu Pier
- Sepulveda Adobe
- Sycamore House, Point Mugu State Park

Other structures in SMMNRA:

- Stokes adobe at Gillette Ranch
- Wallace Neff designed buildings at Gillette Ranch
- Dunbar McBride ruins
- Historic Structures in Coldwater Canyon Park
- Campo de Cahuenga
- Malibu Pier
- Santa Monica Pier

- Loeff’s Hippodrome
- Roads — see landscapes
- Tunnels
- Franklin Canyon Dams
- Malibu Dam and Lake
- Lake Eleanor Dam
- Lake Sherwood Dam
- Rindge Dam
- Lake Shrine

Significant structures outside of SMMNRA:

- Hollyhock House
- Hollywood Bowl
- Reagan Library
- Leonis Adobe
- El Pueblo State Historic Site
- Greystone Doheny Mansion
- Los Encinos State Historic Park
- Reyes Adobe
- Stagecoach Inn
- Getty Malibu Museum
- Skirball Museum
- UCLA Structures
- Veterans Cemetary & Buildings
- Rocketdyne Rocket test structures
- Camarillo Hospital

Museum Collections

More than 250,000 museum objects, specimens and archives are stored in the SMMNRA storage facility at Rocky Oaks. The collections are organized into seven broad categories — archeology, ethnology, history, archives, biology, paleontology, and geology — and provide evidence of activities that brought them into being and information about associated people, organizations, events, and places. The collections serve as reference material for staff and students, and documented material for public exhibit and programs. The physical condition of the SMMNRA collections is generally good to excellent, and the present curation facility at Rocky Oaks meets NPS standards (36 CFR 79) in regard to environmental control, fire protection, and security. However, the facility has some unique considerations in terms of fire management and protection. The building sits on a knoll in a well-known fire corridor.

In addition to the Museum Research building at Rocky Oaks, the following additional buildings may house or contain NPS museum objects:

- Visitor's Center at SMMNRA Headquarters
- Satwiwa Cultural Center
- Tack Room at Rancho Sierra Vista
- Wagon Storage Area at Rancho Sierra Vista

Ethnographic Resources

Ethnographic resources are defined by the National Park Service as any "*...site, structure, object, landscape, or natural resource feature assigned traditional, legendary, religious, subsistence, or other significance in the cultural system of a group traditionally associated with it*" (Cultural Resource Management Guidelines, 1996). The Santa Monica Mountains were, and are, the home of two of the largest groups of Native American Indians in California: the Chumash and the Gabrielino/Tongva. Ethnographic sites of the contemporary Chumash and Gabrielino/Tongva preserve and reflect their traditional values.

The SMMNRA has held regular consultations with the region's contemporary Native American Indians since the recreation area's founding, and members of the region's Native American Indian community have shared their knowledge and skills with the SMMNRA. One result of the consultations is the identification of significant areas in the Santa Monica Mountains that require protection, such as Boney Ridge, the Western slope of the Santa Monica Mountains, Point Dume, Mugu, Santa Monica Canyon, Satwiwa (Round Mountain), Saddle Rock, Castle Peak, El Escorpion, Burro Flats, El Encino, University Springs, Saddle Peak, Seminole Hot Springs, and of course, all villages, cemetaries, caverns, and pictographs, where Native American Indians have a long and deeply spiritual history of interaction.

Cultural Landscapes

Cultural landscapes within NPS-owned and managed lands in SMMNRA can be identified by their connection with particular historic land uses that revolve around general themes of the National Park Service Thematic Framework (1996). Each cultural landscape contains component features that include barns, corrals and fences, farmhouses, archaeological sites, roads and trails, water-management structures, and introduced vegetation and landscaping. All of these landscape features possess tangible evidence of the activities and habits of the people who occupied, developed, used, and shaped the land to serve their needs. The dynamic processes of landscape evolution in the Santa Monica Mountains region have resulted in physical and temporal overlap of a variety of cultural landscapes.

The *Land Protection Plan* and the *General Management Plan* recognize a hierarchy of NPS responsibility that is most direct on NPS owned land, extends to NPS proposed acquisitions, and a cooperative preservation responsibility within the SMMNRA boundaries, and extending into the Santa Monica Mountain Zone. Thus, in the level 0 inventory, landscapes are identified which are not directly managed by the NPS, but which are important contributors to the SMMNRA and in which we have cooperative responsibilities.

Much additional work needs to be done to study and document the importance of these landscapes, to evaluate them according to National Register criteria and seek determinations of eligibility for the National Register. In addition, other agencies such as the California Department of Parks and Recreation (CDPR), California Office of Historic Preservation, Native American Indians, and other stakeholders need to be consulted. A preliminary list of cultural landscapes can be found in Appendix 2 of the General Management Plan. Paramount Ranch has been determined to be a nationally significant cultural landscape. Rancho Sierra Vista (both NPS and CDPR) has been determined to be a significant historic district. Other landscape studies are in process.

Following is a partial listing of the Cultural Landscape Inventory:

- Santa Monica Mountains Chumash / Tongva Ethnographic & Archeological District
- Other Ethnographic / Archeological Areas
- Archeological District (Features)
- Mission / Rancho Landscape
- Ranching and Homesteading Landscapes
- Rancho Sierra Vista Historic Ranching District
- Simi Hills (Palo Comado, Cheeseboro, Upper Las Virgenes Canyons) Historic Ranching District (Landscape)
- Los Encinos State Historic Park
- White Horse Farm (Landscape)
- Reagan Ranch (Landscape)
- Stunt Ranch (Landscape)
- Mason Homestead (Landscape)
- Decker Homestead (Landscape)
- Beach Recreation Landscape

- Medea/Triunfo Valley Cinema Landscape
- Paramount Movie Ranch
- Franklin Canyon Landscape
- Solstice Canyon
- Will Rogers Ranch (Landscape
- Adamson House (Landscape)
- Transportation Corridors
- Ethnographic trade routes
- Mulholland Highway Scenic Corridor
- Pacific Coast Highway/Roosevelt Highway
- Malibu/Las Virgenes
- Decker Canyon
- Potrero Road/Long Grade Canyon 180
- Old Topanga Canyon
- El Camino Real
- Cahuenga Pass/Campo de Cahuenga
- Terminus of Route 66 (at Santa Monica Pier)
- De Anza Trail
- Portola Sacred Expedition 1769
- Hueneme, Malibu, Port Los Angeles Railroad
- Other Historic Transportation Routes
- Hidden Valley Cooperative Planning Area
- Lake Sherwood Cooperative Planning Area
- Topanga Canyons Developed Area
- Malibu/Monte Nido Developed Areas
- Malibou Lake Developed Area
- Pacific Palisades
- Other Designed Landscapes

Fire Impacts on Cultural Resources

A summary of direct, operational, and indirect fire effects is presented below, followed by an explanation of the measures chosen for the types, duration and intensity of impacts described in the impacts analysis section (4B, page 4-55).

Direct, Operational, and Indirect Effects

Direct Effects

As summarized in Appendix B, cultural resources vary in terms of their susceptibility to direct fire effects. For example, obsidian hydration rinds are generally impacted at temperatures in excess of 100 to 150° C, dimensional lumber ignites at 350° C, glass melts at around 500° C, and cast iron at 1400° C. Duration of heating is less well understood, but in general, the longer a resource is exposed to heat, the greater the likelihood of damage. Fire can result in the complete elimination of an artifact or feature (e.g., through consumption) or can alter attributes of an artifact or feature such that important research (e.g., obsidian hydration rinds, residues on pottery, bone burning), traditional (e.g., Native American spiritual sites) or other values are impacted.

Fires tend to burn in a complex manner depending on fuels, weather, and terrain (Ryan and Noste, 1985). Fire intensity is generally greater under conditions of heavier fuel (e.g., dead and down trees, brushfields), low fuel moisture, high air temperatures, high winds, low humidity, and/or rugged terrain. It is the behavior of a fire (ground, surface, and crown) and proximity to a cultural resource that will determine the amount and type of damage that could occur. While running surface fires and crown fires reach extreme temperatures (500 to 1500° C) and have high energy release rates, relatively little of that heat is directed towards the surface of the ground, and ground fires can result in long duration heating (400 to 700° C) within the upper 15 cm of the soil profile. Only under rare conditions (e.g., burning tree roots) will elevated temperatures penetrate more deeply beneath the ground surface. Ground and creeping, and active surface fires are usually associated with prescribed burns, whereas running surface and crown fires occur primarily during wildfires. Very generally, cultural resources located above the ground surface (e.g., rock imagery panels, historical structures) are most vulnerable to direct fire effects during crown and active surface fires, while ground and creeping surface fires threaten those found at, or just below, the ground surface (e.g., archeological sites).

Operational Effects

Operational effects to cultural resources are most likely to occur as a result of fire management actions associated with prescribed burns, wildfires, and mechanical thinning. The operational effects on cultural resources have been quantified in relatively few cases. However, several generalizations can be made:

- Impacts resulting from the operation of heavy equipment on, and in close proximity to, cultural resources will correlate directly with the nature and extent of the disturbance, nature of local sediments, and nature and extent of cultural resources.

- With the exception of those that result in more intense fire behavior (e.g., slash piles, firing techniques), impacts resulting from operational effects will generally be restricted to the displacement, breakage, and/or destruction and looting of cultural resources. In this sense, operational effects tend to be less encompassing than direct effects. For example, an obsidian projectile point displaced by construction of a fire line will probably retain its hydration rind, morphology, and other attributes.

- Except in rare situations, operational effects are likely to be most pronounced on cultural resources found on and near the ground surface.
- Operational effects will be most likely to occur, and at the greatest intensity, during wildfires. This is due primarily to the fact that such actions are often carried out with little or no pre-planning and without consultation or supervision by a cultural resource specialist.

Indirect Effects

Indirect effects are perhaps the most elusive of all, since the impacts may be delayed and incremental. The potential for indirect effects will relate strongly to the context in which a cultural resource is found, the nature of that resource, and the type and extent of the disturbance activity. In most cases, intense fire behavior and major suppression efforts associated with wildfires will render cultural resources vulnerable to indirect effects soon after the event. Indirect effects may not be as pronounced following managed actions such as prescribed burns or mechanical thinning, but can, given enough time, have equally adverse consequences.

Type of Impacts

In general, direct effects of fire management actions on cultural resources will be adverse. This is particularly true of archeological resources, structures, and museum objects. While direct fire effects can also adversely impact ethnographic resources and cultural landscapes, fire can also be used to restore, enhance, and maintain them. For example, in regard to ethnographic resources, some plants important for basketmaking benefit from the proper application of fire (Anderson, 1999). In cultural landscapes with a vegetation component, fire can be applied to replicate and maintain historic scenes. Adverse direct effects are more likely to occur during extreme fire behavior such as wildfires, although cultural resources with high vulnerability to fire are susceptible to low intensity burns often associated with prescribed fire.

Operational effects of fire management actions on cultural resources will, in most cases, be adverse. However, the degree of impact depends greatly on the nature of the operation and the cultural resource or resources in question. Adverse operational effects are of particular concern during and after wildfire events. With proper planning, operations can also be used for beneficial purposes. For example, mechanical thinning can effectively remove hazardous fuels from, and in the vicinity of, cultural resources, as well as restore, enhance, or maintain ethnographic resources and cultural landscapes, in cases where the risk of direct effects is too high.

Finally, the indirect effects of fire management actions generally adversely affect cultural resources, especially those that follow high intensity wildfires.

Duration of Impacts

With respect to archeological resources, structures and cultural landscapes, short and long term impacts related to fire management actions are distinguished based on the number of years (10 and 20, respectively) before effects manifested following the action. These numbers were selected somewhat arbitrarily, and subject to revision as monitoring data are gathered. Impacts of short and long term duration differ from those of permanent duration, where significant characteristics of a resource of interest are irrevocably compromised during the action. Intervals utilized for ethnographic resources and museum objects are configured somewhat differently given variations in the use and nature of these resources.

The duration of direct, operational, and indirect effects on fire management actions is influenced strongly by the nature of the action and fire intensity. For example, a high intensity wildfire will tend to result in more adverse permanent effects than a low intensity prescribed burn. Likewise, a suppression effort using heavy equipment has a higher likelihood of more adverse operational and indirect effects than one with hand lines. Adverse effects resulting from fire management actions vary in regard to timing. For example, some archeological resources will be totally consumed by the burn, while others will be modified such that deterioration will occur more rapidly following the burn. Ethnographic resources and cultural landscape features may recover slowly following fire management actions. However, fire can also be used to protect certain cultural resources by reducing adjacent fuel loads, or, in the case of ethnographic resources or cultural landscapes, restore, maintain, and/or enhance them.

Intensity of Effects

The intensity of direct fire effects is difficult to quantify. This is due in part to the poor understanding of these effects, as well as the apparent differential vulnerability of the various cultural resource classes. Because of this, it is probably better to consider potential direct effects to individual components of a particular resource class (e.g., flaked stone, groundstone, bone, shell in a Native American village) rather than the resource class as a whole (e.g., lithic scatters, villages, trash scatters, mines for archeological resources). As noted, however, even within individual components, direct fire effects differentially impact various attributes of a particular artifact or feature type. For example, potential direct fire effects on an obsidian artifact include alteration of the obsidian hydration rind, inability to chemically source, breakage, melting, discoloration, and elimination of organic residues, each of which can occur at different temperatures and/or duration of exposure.

Ideally, an assessment of the intensity of potential direct effects on cultural resources at SMMNRA would be conducted in conjunction with fire temperature data for each fuel model/vegetation community, detailed fire history studies, and accurate inventory of the types and distribution of cultural resources found in the unit. Unfortunately, this is not the case. While computer models predicting the intensity and severity of fire behavior based on a number of variables are available, predicting direct fire effects on cultural resources from the outputs is not well developed. For example, most experiments measuring the effects of fire on cultural resources utilized temperature as the agent of change, while computer models provide estimates of fire line intensity in non-comparable British Thermal Units (BTUs).

Still, some generalizations can be put forth with regard to evaluating potential direct fire effects. In most cases, the greater the fuel load, the more intensely a fire is likely to burn (DeBano et al., 1996:56). Table 3-12 depicts the distribution of recorded archeological sites in SMMNRA with respect to dominant vegetation communities. The majority of sites are found in chaparral and coastal sagebrush communities, which are also the dominant vegetation communities in SMMNRA. Anticipated fire behavior in these communities is expected to be moderate to high depending on weather conditions and other factors. While temperature thresholds above which various classes or attributes of cultural resources can be adversely effected are not readily identifiable, it can be assumed that highly vulnerable data like wooden structures and features and organic residues have the potential to be impaired at even the lowest fire intensities, and fires in chaparral will have the potential to impart the greatest damage.

Table 3-12 Distribution of Known Archaeological Sites by Vegetation Type

Vegetation Type	% Arch. Sites	% Total Area	Relative Proportion of Archaeological Sites to Land Area
Agriculture/development	24.5	12.9	1.9
Chaparral[1]	26.8	54.4	0.5
Coastal Sage Scrub[2]	30.4	22.4	1.4
Woodlands and Oak Savannah[3]	10.2	5.4	1.9
Non-native Grassland[4]	7.4	3.9	1.9
Rock outcrops	0.6	0.3	2.0

[1] chamise chaparral, northern mixed chaparral, red-shank chaparral

[2] coastal sage scrub, coastal cactus scrub, coastal dune/bluff scrub, css-chaparral transition, coastal strand

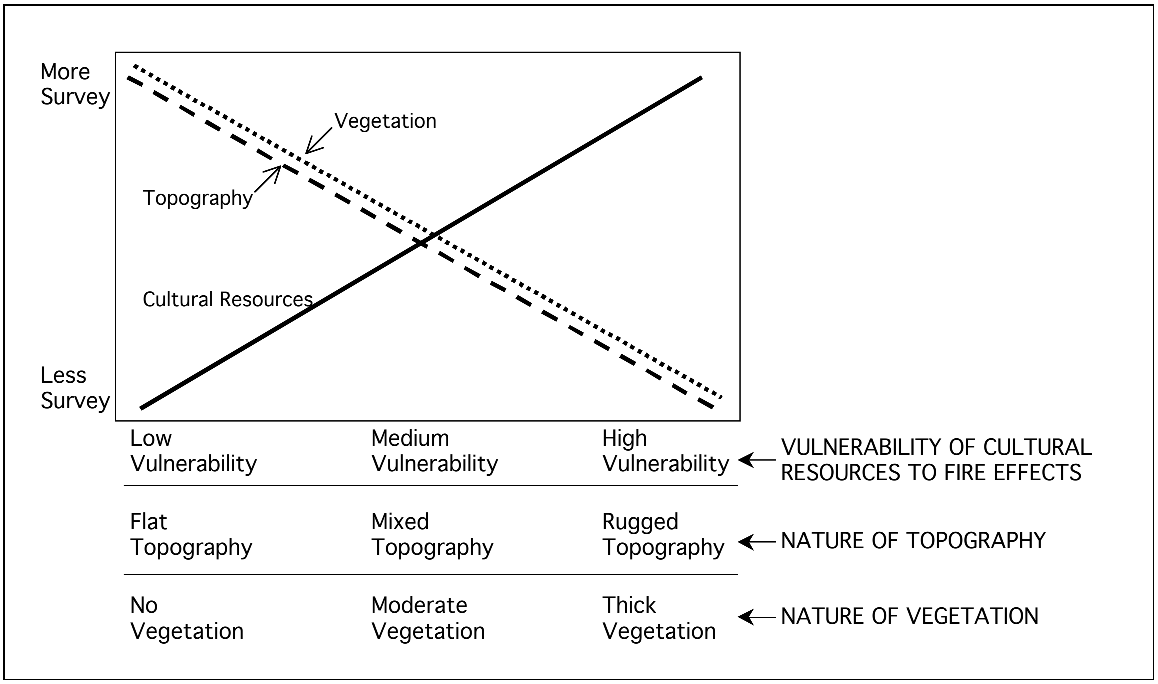
[3] coast live oak, riparian, valley oak, walnut

[4] non-native grassland, non-native grassland/herbaceous

Past fire activity is relevant in assessing potential direct effects in that fuel loads can be influenced by the frequency of fire. Fire history data reveal that fires have occurred on or near most cultural resources in SMMNRA. Inferences about past fire frequency can also be drawn from topographic variables such as aspect and slope. For example, fire frequency is usually greater on steep, south facing slopes than other orientations.

The accuracy of previous cultural resources surveys at SMMNRA has probably been influenced by a combination of thick vegetation and rugged topography. Ironically, those areas that are most easily traversed (low gradient topography, sparse vegetation) will usually support less intense fire behavior than steep and/or heavily vegetated locations (Figure 3-27). While areas with low topographic gradient were probably the most attractive for settlement, some activities (e.g., mining) were carried out without regard to such considerations. The implication is that it will often be difficult to locate and adequately document cultural resources in areas of thick vegetation and/or steep topography, and that such resources will be highly vulnerable to direct fire effects.

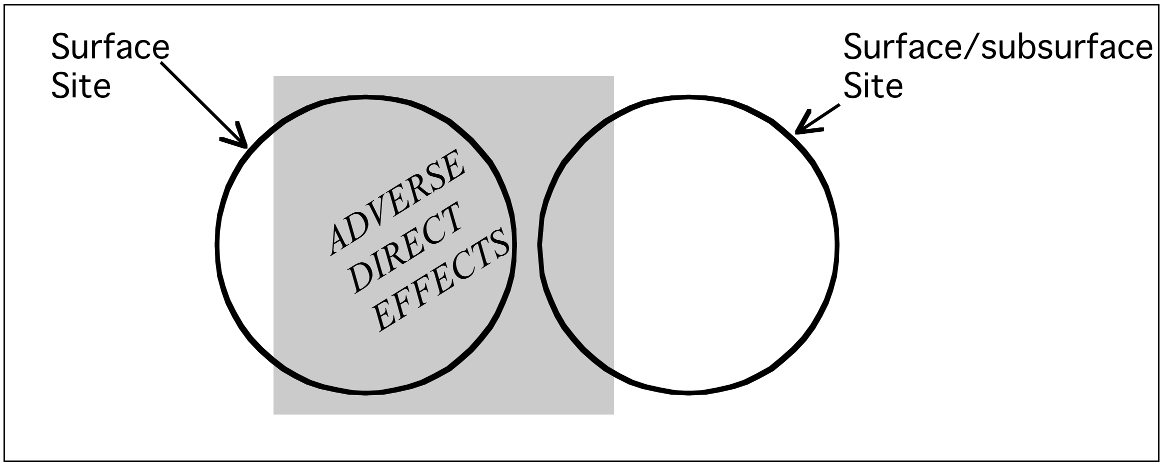
Figure 3-27 Relationship Between Survey Coverage and Vulnerability of Cultural Resources to Fire Effects, Topography, and Vegetation



The volume or extent of a cultural resource vulnerable to direct fire effects also merits consideration. As noted, except under special circumstances, direct fire effects will generally be restricted to those cultural resources found above, on, and slightly below the ground surface. As such, all else being equal, the classes and attributes of cultural resources found exclusively on or near the ground surface are prone to have a greater percentage of their number adversely impacted by direct fire effects than those resources with a combination of surface and subsurface material. This is significant because cultural resources generally considered to have high data potential, such as Native American villages with subsurface components, may actually have a far lower percentage of artifact classes or attributes exposed to direct fire effects than a lithic scatter, often considered to have low data potential, that is restricted to the ground surface (Figure 3-28). While it is the village that would probably receive the greatest amount of attention in regard to a planned or unplanned fire management action, it is the lithic scatter that has the potential to undergo the greatest intensity of impact.

Figure 3-28 Susceptibility of Cultural Materials in Surface and Surface/Subsurface Contexts to Direct Fire Effects

Open circles reflect the full range of artifact classes/attributes represented at each site type, and the amount of overlap with the shaded circle represents the amount or percentage of artifact classes/attributes vulnerable to adverse effects.



Determining if and/or to what extent a cultural resource has subsurface components is best accomplished through invasive (e.g., excavation, auguring) or non-invasive (e.g., remote sensing, cut bank inspection) means. Relatively few of these studies have been carried out at sites in SMMNRA. While people do intentionally and unintentionally bury cultural materials (e.g., trash dumps, yucca ovens, burials), it is geomorphological processes that dictate whether a given cultural resource is likely to have a subsurface component. In general, toeslopes, footslopes, and terraces will have greater accumulations of colluvium and alluvium than summits and sideslopes, from which these sediments are eroding. It is suspected that these processes are particularly pronounced in some locations at SMMNRA. In the absence of invasive or non-invasive investigations, inferences about the presence and extent of subsurface components can be drawn based on the geomorphological context in which a resource is found.

VI Social Environment

A Land Use

The SMMNRA exists as a mosaic of parklands and private land holdings across more than 150,000 acres in southern California. The park boundary extends through both Los Angeles and Ventura Counties and includes all or portions of the communities of Agoura Hills, Calabasas, Beverly Hills, Malibu, Pacific Palisades, Thousand Oaks, Topanga, Westlake Village, and Los Angeles. This complex array of land uses, land owners, and jurisdictions strongly influences fire risk and fire management options.

Development in and around the SMMNRA has created an unprecedented wildland urban interface amid the highly fire prone landscape of the Santa Monica Mountains. Residential developments occur throughout the park, including high-density subdivisions along with more scattered rural homes on larger lots. Generally, higher-income populations live in these areas since property values are higher than in the more developed suburbs and urban areas nearby. Agricultural uses exist in some parts of the mountains, including large horse ranches and small-scale agriculture (e.g., vineyards). However, commercial agriculture is not common in the park. Industrial and commercial uses comprise a relatively small percentage of the area's existing land use. Throughout the mountains, commuter roads servicing residential developments are also common and two multi-lane freeways parallel and bisect portions of the park, U.S. Highway 101 and Interstate 405. At the same time, over half of the land area in the SMMNRA is protected as parkland, interspersed within the human developments and roads.

The extensive development interface provides numerous fire management challenges. The combination of highly combustible vegetation types, periodic extreme fire weather conditions, and the potential for substantial life and property losses during wildfires mean that park managers, fire management agencies, and local jurisdictions must work together to identify realistic fire management actions that reduce fire risk and protect environmental values.

To reduce fire risk in the developed interface and around structures, local jurisdictions require brush clearance zones and compliance with various fire safety ordinances. In some cases, to maintain adequate brush clearance requires vegetation removal from parklands and other sensitive resource areas. Thus, the ecological consequences of vegetation clearance must be evaluated against information on fire risk and behavior, fuel type, local jurisdiction requirements, and values at risk. Vegetation clearance is clearly important near developed areas and around structures, however, excessive clearance can also impart significant ecological impacts with only slightly improved or negligible improvements in fire hazard reduction. For example, substantial fuel modification and firebreaks have already altered much of the landscape in the Santa Monica Mountains. At the same time, adequate clearance around structures and developments appears to be the most effective way to reduce fire hazard and generally results in fewer impacts than wide scale vegetation clearance far from developments and within undisturbed vegetation. The key is to identify strategic zones for fuel modification that result in the greatest hazard fuel reduction with the least environmental impact.

In addition to vegetation clearance, complex land use patterns and human influences in the SMMNRA also affect fire suppression techniques and associated impacts. With developments scattered across much of the landscape, no wildfire is permitted to burn; full suppression is always employed. Steep-sided canyons and narrow mountain roads constrain access for people and suppression resources, making fire fighting especially challenging and dangerous. Environmental costs of suppression can also be high, with control lines and heavy equipment sometimes leaving long-term scars on the landscape. Suppression-related disturbances can also facilitate exotic species invasions and contribute to erosion if not properly mitigated.

Land use pattern and human activities also contribute to the risk of fire in the SMMNRA because of human-caused ignitions. For example, nearly all large fires (i.e., greater than 10,000 acres) in the mountains since detailed records were kept (beginning in 1925) have been human-caused, either directly or indirectly. Ignition sources have included downed power lines during high wind conditions and direct fire starts from arson. Because of the complex patterns of human development and easy access to the mountains by people, human-caused fires can and have occurred throughout the range. However, observations of fire history maps do suggest that regions of high development prevalence (e.g., along the 101 freeway corridor) tend to produce higher ignition frequencies. As development continues across the mountains one can expect ongoing threats from human-caused wildfire ignitions.

The existing patterns of human development in the SMMNRA interact to result in this challenging array of hazard reduction concerns, fire suppression issues, and ignition source risks. Ongoing development continues, generally guided by established land use plans within each of the local jurisdictions. Although specific land use designations vary by jurisdiction, all distinguish between areas of future development and current open space. Fire management activities, such as hazard fuel reduction zones or suppression actions, have the potential to directly affect developments. Conversely, developments have an impact on fire suppression agencies' abilities to suppress fires as well as provide fire protection services to all the structures that may require suppression efforts during an incident. As a result, the future patterns of development will strongly influence interactions between fire risk, fire management options and consequences, wildfire effects, and environmental quality.

VI Social Environment

B Recreation

The fire risk potential and effects of humans on fire management in the SMMNRA are also influenced by recreational use of the park. Recreation users in remote parts of the mountains can be exposed to risk if evacuations are necessary, particularly during extreme fire weather conditions. In some instances, park managers will choose to close park sites to ensure visitor safety during extreme weather (i.e., strong Santa Ana winds). Conversely, access to remote areas by park users may increase the likelihood of human-caused ignitions in the park, either through unintentional or intentional fire starts.

Throughout the mountains, park sites are heavily used by recreation enthusiasts. Hikers, mountain bikers, and equestrians use literally hundreds of miles of trails. Many park sites accommodate picnickers and some sites offer camping opportunities and locations for special events. In general, visitors come to the parklands to enjoy the area's unique natural, cultural, and scenic resources. Wildfires, fire suppression activities, and fire management actions can affect the ability of park users to access and enjoy the park, and can also affect the scenic qualities of the SMMNRA.

Extensive vegetation clearance and fuel modification zones necessarily remove native vegetation, impacting visual qualities. Prescribed burns can also affect scenic resources by removing visually pleasing vegetation and creating bare areas for control lines and staging areas. For these reasons, planned burns are often scrutinized by the public in terms of the visual effects they may have on park resources. During wildfire events, suppression activities may also leave lasting imprints on the landscape. In addition, high intensity fires may affect vegetation regeneration and frequent fires (including prescribed burns) may lead to type conversion to less visually desirable non-native grasses.

For all fire management actions, including wildfire suppression and control of prescribed burns, control lines and mechanical clearance can lead to trail proliferation. These impacts affect visitor experiences by degrading visual qualities and can facilitate unauthorized access by people into environmentally sensitive areas. This access, in turn, can further reduce resource values by increasing erosion and aiding the invasion of non-native species.

Overall, the importance and prevalence of visitor uses throughout the mountains are influenced by the effects of fire, fire management actions, and fire risk. The NPS and other agencies must consider these interactions when developing fire management and suppression actions, and when evaluating the effects of mechanical fuel reduction, prescribed fire, and wildfire effects on park resources and visitor experience.